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Sockeye Salmon Smolt Investigations on the Chignik River, 2009

by

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and

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July 2010

Alaska Department of Fish and Game Divisions of Sport Fish and Commercial Fisheries

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Weights and measures (metric)

centimeter	cm
deciliter	dL
gram	g
hectare	ha
kilogram	kg
kilometer	km
liter	L
meter	m
milliliter	mL
millimeter	mm

Weights and measures (English)

cubic feet per second	ft^3/s
foot	ft
gallon	gal
inch	in
mile	mi
nautical mile	nmi
ounce	oz
pound	lb
quart	qt
yard	yd

Time and temperature

day	d
degrees Celsius	°C
degrees Fahrenheit	°F
degrees kelvin	K
hour	h
minute	min
second	s

Physics and chemistry

all atomic symbols	
alternating current	AC
ampere	A
calorie	cal
direct current	DC
hertz	Hz
horsepower	hp
hydrogen ion activity (negative log of)	pH
parts per million	ppm
parts per thousand	ppt, ‰
volts	V
watts	W

General

Alaska Administrative Code	AAC
all commonly accepted abbreviations	e.g., Mr., Mrs., AM, PM, etc.
all commonly accepted professional titles	e.g., Dr., Ph.D., R.N., etc.
at	@
compass directions:	
east	E
north	N
south	S
west	W
copyright	©
corporate suffixes:	
Company	Co.
Corporation	Corp.
Incorporated	Inc.
Limited	Ltd.
District of Columbia	D.C.
et alii (and others)	et al.
et cetera (and so forth)	etc.
exempli gratia (for example)	e.g.
Federal Information Code	FIC
id est (that is)	i.e.
latitude or longitude	lat. or long.
monetary symbols (U.S.)	$, ¢
months (tables and figures): first three letters	Jan,...,Dec
registered trademark	®
trademark	™
United States (adjective)	U.S.
United States of America (noun)	USA
U.S.C.	United States Code
U.S. state	use two-letter abbreviations (e.g., AK, WA)

Measures (fisheries)

fork length	FL
mideye-to-fork	MEF
mideye-to-tail-fork	METF
standard length	SL
total length	TL

Mathematics, statistics

all standard mathematical signs, symbols and abbreviations	
alternate hypothesis	H_A
base of natural logarithm	*e*
catch per unit effort	CPUE
coefficient of variation	CV
common test statistics	(F, t, χ^2, etc.)
confidence interval	CI
correlation coefficient (multiple)	R
correlation coefficient (simple)	r
covariance	cov
degree (angular)	°
degrees of freedom	df
expected value	*E*
greater than	>
greater than or equal to	≥
harvest per unit effort	HPUE
less than	<
less than or equal to	≤
logarithm (natural)	ln
logarithm (base 10)	log
logarithm (specify base)	log_2, etc.
minute (angular)	'
not significant	NS
null hypothesis	H_O
percent	%
probability	P
probability of a type I error (rejection of the null hypothesis when true)	α
probability of a type II error (acceptance of the null hypothesis when false)	β
second (angular)	"
standard deviation	SD
standard error	SE
variance	
population	Var
sample	var

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ABSTRACT

This report describes the results of the sockeye salmon *Oncorhynchus nerka* smolt monitoring and enumeration project conducted by the Alaska Department of Fish and Game (ADF&G) in the Chignik River watershed in 2009. The research in 2009 was designed to estimate smolt population size and age structure, describe limnotic habitat conditions and forage base, assess fish body condition, collect samples for genetic stock identification, and provide an alternative adult forecast in 2010 to compare to the formal Chignik River sockeye salmon forecast. The abundance of sockeye salmon smolts was estimated using a rotary-screw trap array and mark-recapture techniques. In 2009, a total of 8,176,509 sockeye salmon smolts were estimated to pass downstream of the traps from May 6 to July 7. Of these, 110,446 (1.4%) were age-0., 3,777,572 (46.2%) were age-1., and 4,288,491 (52.4%) were age-2. smolts. Limnological surveys were conducted in Chignik and Black lakes each month from May to August 2009, to describe the physical characteristics, nutrient availability, primary production, and zooplankton forage available to rearing juvenile sockeye salmon. Top-down grazing was suggested by relatively high primary production, but relatively low zooplankton populations from May through July in Black Lake, and from May through June in Chignik Lake.

The Chignik River watershed 2010 sockeye salmon run was formally forecasted at 2.2 million fish, with an expected harvest of 1.6 million fish, using sibling and temperature index relationships. This formal forecast is supported by a secondary forecast using smolt age and abundance data from 2009.

Key words: Sockeye salmon, smolt, *Oncorhynchus nerka,* Chignik River, forecast, mark-recapture, zooplankton.

INTRODUCTION

The Alaska Department of Fish and Game (ADF&G) has monitored the sockeye salmon *Oncorhynchus nerka* smolt emigration in the Chignik River annually since 1994 to gauge the health of smolts leaving the system, estimate the marine survival of sockeye salmon smolts, and provide a preseason forecast of the Chignik River watershed sockeye salmon run.

The Chignik River watershed produces the vast majority of the sockeye salmon in the Chignik Management Area (Bouwens 2004), and consists of a large, shallow lagoon, two large lakes, and several tributaries that provide spawning and rearing habitat for sockeye salmon (Figure 1). Black Lake, at the head of the system, has a surface area of approximately 35.7 km^2 and is atypically shallow (maximum depth 4.2 m) and turbid for a sockeye salmon nursery lake, because it sits in a shallow tundra depression (Griffiths et al. 2009). In contrast, Chignik Lake is smaller (22 km^2), deep (maximum depth 64 m) and surrounded by mountains. Black Lake drains via the Black River into Chignik Lake, which flows through Chignik River into Chignik Lagoon, and then into the Gulf of Alaska (Narver 1966; Dahlberg 1968). Chignik Lagoon is a semi-enclosed estuary with salinities ranging from full marine seawater at the outer spit to nearly freshwater conditions at the head of the lagoon (Simmons 2009).

Both lakes are considered oligotrophic (Kyle 1992) and each maintains its own genetically distinct, but temporally overlapping, runs of adult sockeye salmon (Templin et al. 1999). The early run enters the watershed from June through mid July and spawns in Black Lake and its tributaries. The late-run returns from late June through the late fall and spawns in the tributaries and shoals of Chignik Lake. The early run has a sustainable escapement goal (SEG) range of 350,000 to 400,000 fish through July 4, while the late run has an SEG range of 200,000 to 400,000 fish beginning on July 5 and an additional 50,000 fish inriver run goal (IRRG) apportioned between August and September (Witteveen et. al 2007).

Since the inception of the sockeye salmon smolt enumeration project in 1994, estimates of sockeye smolt emigrations from the Chignik River watershed have ranged from two to 26 million sockeye salmon (Finkle and Ruhl 2008). Chignik sockeye salmon smolts generally have been observed to migrate from the watershed beginning in early May, peaking in mid to late May and are predominantly composed of age-1. and -2. fish (Finkle and Ruhl 2008). Emigration timing differences between stocks is theorized, but genetic analysis has not yet been undertaken to determine whether this occurs.

Juvenile salmon are known to migrate to sea after certain size thresholds are met, during specific seasons, and under certain environmental conditions (Clarke and Hirano 1995). It is difficult to directly measure the interactions and impacts of these effects on juvenile fishes. Salmon smolt emigration may be triggered by warmer springtime water temperatures (~ 4°C) and increased photoperiod (Clarke and Hirano 1995). Variables affecting growth in juvenile salmon include temperature, competition, food quality and availability, and various water chemistry parameters (Moyle and Cech 1988). Because of these dynamic factors, annual growth of juvenile sockeye salmon often varies among lakes, years, and within individual populations (Bumgarner 1993).

Sockeye salmon rearing in Chignik and Black lakes are exposed to varying levels and types of environmental stresses which may influence their life history strategies. For example, if growth rates are not sufficient to achieve the threshold size necessary to emigrate in the spring, juvenile fish may stay in a lake to feed for another year (Burgner 1991), possibly increasing competition among younger age classes in the same rearing area. The usage of available rearing habitat specific to each stock, and interactions between the Black Lake (early run) and Chignik Lake (late run) stocks are not completely understood, but have been the focus of numerous studies (Bumgarner 1993; Ruggerone 2003; Westley et al. 2008; Simmons 2009; Westley et al. 2009). In particular, the influence of changing physical and environmental factors upon the emigration of juvenile sockeye salmon merits continued investigations. Other past studies have also suggested that a component of juvenile sockeye salmon rear in the Chignik River and Chignik Lagoon during the summer to offset or avoid overtaxed Chignik Lake rearing conditions, and subsequently return to Chignik Lake in the fall of the same year (Roos 1957, 1959; Iverson 1966; Phinney 1968). Smolt emigration studies can provide information on life history strategies, annual changes in emigration timing, and when combined with limnological investigations, provide insight as to how environmental factors may influence juvenile behavior such as emigration timing, overwintering habitat selection, and impacts on food availability.

Density dependent limitations such as competition for food and habitat can influence migratory behavior of sockeye salmon juveniles (Rice et al. 1994). Over the past several decades, mean annual temperature and precipitation (as measured at Cold Bay, Alaska; Alaska Climate Research Center) has increased, while Black Lake water levels have decreased to two-thirds of the 1968 mean depth of 3.0 m (Dahlberg 1968; Ruggerone et al. 1993). Changes in temperature regimes and the loss of Black Lake rearing habitat may create thermally stressful environments for juvenile sockeye salmon, and stress the available forage base, intensifying competition and top-down pressures on zooplankton by juvenile salmon. Recent work in the watershed (Finkle 2004; Westley and Hilborn 2006; Simmons 2009) indicates Black Lake juveniles move into Chignik Lake to overwinter, with possible deleterious effects on Chignik Lake juveniles. Top-down pressures are often indicated by decreased zooplankton size, which has been observed in *Bosmina* from Chignik and Black lakes (Kerfoot 1987; Kyle 1992; Bouwens and Finkle 2003). Competition for space and food between populations of juvenile sockeye salmon in Chignik Lake may cause seasonal migrations of either subpopulation into areas of lower smolt density and possibly migration into Chignik Lagoon. Information derived from smolt and watershed monitoring is crucial for understanding changes in the production capacity of the salmon habitat of both Black and Chignik lakes.

Smolt emigration data can serve as an indicator of future run strength and overall stock status. In recent years, abundance and age data from the enumeration project have been combined into a model used to generate an adult sockeye salmon forecast for the Chignik watershed (Finkle and Ruhl 2008; Eggers et. al 2010). Forecasts enable harvesters and fish processors to estimate their potential supply and production needs. Current formal forecast methods used to predict the adult runs to the Chignik watershed employ historic age class relationships for the early run and return-per-spawner relationships for the late run (Eggers et. al 2010). Smolt emigration estimates by age are expected to add accuracy to the forecast models currently used. Additionally, genetic identification of emigrating Chignik smolts has been undertaken in recent years to provide insight to annual fluctuations in the population size of each emigrating stock. Genetic studies will also elucidate potential differences in emigration timing between stocks and will provide further detail for stock-specific return predictions.

In addition to smolt abundance and condition information collected at the smolt trap, additional information on rearing conditions within the Chignik River watershed are needed to determine what other factors may affect sockeye salmon production. Limnological investigations in the Chignik watershed have occurred annually since 2000, and in 2008, limnological studies were formally incorporated into the smolt enumeration project. To date, limnology and smolt data from the Chignik watershed have been used to describe top-down limitations to rearing sockeye salmon and trends in the life history strategies of juvenile sockeye salmon relative to recent physical changes to the watershed (Buffington 2001; Bouwens and Finkle 2003; Finkle 2004). The limnology portion of this study seeks to identify and understand the relationships among the Chignik watershed, its juvenile sockeye salmon, and zooplankton relative to physical conditions such as temperature, turbidity, dissolved oxygen saturation of the water, and available nutrients such as nitrogen and phosphorous.

The 2009 field season was the sixteenth year of the ADF&G Chignik River sockeye salmon smolt monitoring and enumeration project which has been funded by the Chignik Regional Aquaculture Association (CRAA) since inception. The sampling protocol has been consistent for these 16 years. This report presents data collected in 2009, compares the results of 2009 to other years, and provides the 2010 adult sockeye salmon forecast based on smolt data.

OBJECTIVES

The objectives for the 2009 season were to:

1) estimate the total number of emigrating sockeye salmon smolts, by age, from the Chignik River watershed;
2) describe emigration timing and growth characteristics (length, weight, and condition factor) of sockeye salmon smolts by age for the Chignik River watershed;
3) continue to build a smolt-based forecast model in an effort to estimate marine survival and future runs;
4) present a stewardship-building sockeye salmon smolt presentation to students at Chignik Lake school;

5) collect genetic samples from emigrating sockeye salmon smolts for use in a future stock separation study;
6) describe the physical characteristics of Black and Chignik lakes, including temperature, dissolved oxygen, and light penetration profiles;
7) describe the nutrient availability and primary production of Black and Chignik lakes; and
8) describe the zooplankton forage base available to juvenile sockeye salmon in Black and Chignik lakes.

METHODS

STUDY SITE AND TRAP DESCRIPTION

Two rotary-screw traps were operated side by side to capture smolts emigrating from the Chignik watershed. Another trap was modified and used as a live box and work station platform. The live box was placed behind the small trap, which was closest to shore. The trapping site was located 8.6 km upstream from Chignik Lagoon and 1.9 km downstream from the outlet of Chignik Lake (lat. 56°15'26" N, long. 158°43'49" W; Figure 2). The traps were located near a bend in the river with the highest current and narrowest span.

Each trap was secured to shore with highly visible polypropylene line. The highly visible line and a strobe light attached to the safety railing of the offshore trap were employed to address safe navigation around the traps and anchor lines for local boat traffic. The strobe was positioned far enough behind the mouth of large trap to minimize trap avoidance by sockeye salmon smolts.

Each trap consisted of a cone constructed of aluminum perforated plate (5-mm holes) mounted on two aluminum pontoons, with the large open end of the cone pointed upstream. The cone mouth diameter was 1.5 m on the small trap (placed nearshore), and 2.4 m on the large trap (placed offshore). The small trap sampled an area of approximately 0.73 m^2, and the large trap sampled an area of approximately 2.0 m^2 of the river's profile because only the bottom portion of the cone was submerged. The river current propelled an internal screw welded to the inside of each cone, which rotated the cones at approximately 3–9 revolutions per minute (RPM) during average water flow conditions. Fish were funneled through the cones into live boxes, each approximately 0.7 m^3 in volume. The live boxes sat on the downstream end of each trap. A pair of adjustable aluminum support legs was utilized to maintain and adjust the traps' positions from the shore and their orientation in the current.

A floating platform for a 3m x 4m weatherport was tied directly behind the live box work station. The weatherport provided shelter for the crew when processing samples taken from the traps.

During the 2009 field season, both of the traps were operated continuously from 1000 hours on May 6 to 1035 hours on July 7. At the completion of the project, both traps were disassembled and stored.

SMOLT ENUMERATION

Because smolts primarily emigrate at night, sampling days extended for a 24-hour period from noon to noon and were identified by the date of the first noon-to-midnight period. The traps were checked a minimum of three times each day beginning at noon, between 2000 and 2200 hours, and no later than 0800 hours the next morning. Traps were checked more frequently during periods of increased smolt emigration, on an average of every three hours, and every six hours during the night.

Juvenile sockeye salmon greater than 45 mm fork length (FL; measured from tip of snout to fork of tail) were considered smolt (Thedinga et al. 1994). All fish were netted out of the traps' live boxes, identified (McConnell and Snyder 1972; Pollard et al. 1997), and enumerated. Sockeye salmon fry (< 45 mm FL), coho salmon *O. kisutch* juveniles, Chinook salmon *O. tshawytscha* juveniles, Dolly Varden *Salvelinus malma*, stickleback of the family Gasterosteidae, pond smelt *Hypomesus olidus*, pygmy whitefish *Prosopium coulteri*, starry flounder *Platichthys stellatus*, coastrange sculpin *Cottus aleutus*, and the isopod *Mesidotea entomon* (Merrit and Cummings 1984; Pennak 1989) were also identified and counted.

The number of smolts emigrating during any time period when the traps were not operating was estimated from known counts during adjacent time periods, using time series analysis in SYSTAT (SYSTAT Software, Inc.). Autocorrelation diagnostic tests (plots of autocorrelation function and partial autocorrelation function) were run to assess and correct for autocorrelation. Such time periods without gear operation could occur early in the season before traps are installed, during the season from trap malfunction or breakdown, or at the end of the season after the traps are removed from the river. If the period of missed counts occurred at the beginning or end of the season, the SYSTAT function estimated the number of smolts by extrapolating from known counts after the trap was installed or before it was removed for the season. If the period of missed counts occurred during the season, the SYSTAT function estimated the number of smolts by interpolating from the known counts on the days before and after. Such approaches are standard on biological monitoring projects (Chatfield 1985; Geiger and Zhang 2002; Shotwell and Adkinson 2004).

TRAP EFFICIENCY AND SMOLT POPULATION SIZE ESTIMATES

Mark-recapture experiments were conducted weekly to determine trap efficiency when a sufficient number of smolts were captured to conduct a marking event. Between approximately 700 and 4,000 sockeye salmon smolts for each experiment were collected from the traps and transferred to the live box. Smolts were retained in the live box for no more than three nights if sufficient numbers were not initially captured to perform a mark-recapture experiment. Past mark retention and delayed mortality experiments indicated that most of the captured smolt mortalities occurred within the first three days of capture (Bouwens and Newland 2003). Thus, after three nights, all captured live smolts were marked if the minimum sample size was met or released if the minimum sample size was not met.

Sockeye salmon smolts were netted from the live box, counted, and transferred into an aerated repository containing a Bismarck Brown Y dye solution (4.6 g of dye to 92.4 L of water) for 15 minutes. Fresh water was then pumped into the container to slowly flush out the dye (90 min). The smolts were allowed to recover in the circulating water. At the end of the marking process, any dead or stressed smolts were removed, counted, and disposed of downstream of the traps.

The remaining marked smolts were taken to the upriver release site (lat. 56°15'15" N, long. 158°44'51" W), approximately 1.3 km upstream of the traps (Figure 2). The smolts were transported upstream in aerated containers and released evenly across the breadth of the river from the south bank to the north bank. The marking event was performed so that the marked fish were released before midnight. The number of smolts recaptured in the traps was recorded for several days until recoveries ceased. Sockeye salmon smolts recaptured during mark-recapture experiments were recorded separately from unmarked smolts and excluded from daily total catch to prevent double counting.

The trap efficiency E was calculated by

$$E_h = \frac{(M_h + 1)}{m_h + 1} \tag{1}$$

where

h = stratum or time period index (release event paired with a recovery period),

M_h = the total number of marked releases in stratum *h,*

and

m_h = the total number of marked recaptures in stratum *h*.

The Chignik River watershed smolt population size was estimated by using methods described in Carlson et al. (1998). The approximately unbiased estimator of the total population within each stratum ($\hat{U}_h$) was calculated by

$$\hat{U}_h = \frac{u_h(M_h + 1)}{m_h + 1}, \tag{2}$$

where

u_h = the number of unmarked smolts captured in stratum *h,*

Variance was estimated by

$$v(\hat{U}_h) = \frac{(M_h + 1)(u_h + m_h + 1)(M_h - m_h)u_h}{(m_h + 1)^2(m_h + 2)}. \tag{3}$$

The estimate of $\hat{U}$ for all strata combined was estimated by

$$\hat{U} = \sum_{h=1}^{L} \hat{U}_h, \tag{4}$$

where L was the number of strata. Variance for $\hat{U}$ was estimated by

$$v(\hat{U}) = \sum_{h=1}^{L} v(\hat{U}_h), \tag{5}$$

and 95% confidence intervals were estimated from

$$\hat{U} \pm 1.96\sqrt{v(\hat{U})}, \tag{6}$$

which assumed that $\hat{U}$ was asymptotically normally distributed.

The estimate of emigrating smolts by age class for each stratum *h* was determined by first calculating the proportion of each age class of smolt in the sample population as:

$$\hat{\theta}_{jh} = \frac{A_{jh}}{A_h}, \tag{7}$$

where

A_{jh} = the number of age *j* smolts sampled in stratum *h,* and

A_h = the number of smolts sampled in stratum *h*

with the variance estimated as

$$v\left(\hat{\theta}_{jh}\right) = \frac{\hat{\theta}_{jh}\left(1-\hat{\theta}_{jh}\right)}{A_h}\ . \tag{8}$$

For each stratum, the total population by age class was estimated as

$$\hat{U}_{jh} = \hat{U}_j\hat{\theta}_{jh}, \tag{9}$$

where $\hat{U}_j$ was the total population size of age *j* smolt, excluding the marked releases (=$\sum U_{jh}$).
The variance for $\hat{U}_{jh}$, ignoring the covariance term, was estimated as

$$v\left(\hat{U}_{jh}\right) = \hat{U}_h^{\,2} v\left(\hat{\theta}_{jh}\right) + \hat{U}_h v\left(\hat{\theta}_{jh}\right)^2. \tag{10}$$

The total population size of each age class over all strata was estimated as:

$$\hat{U}_j = \sum_{h=1}^{L} \hat{U}_{jh}, \tag{11}$$

with the variance estimated by

$$v\left(\hat{U}_j\right) = \sum_{h=1}^{L} v\left(\hat{U}_{jh}\right). \tag{12}$$

AGE, WEIGHT, AND LENGTH SAMPLING

A daily sample of 40 sockeye salmon smolts was collected on five days per statistical week for age-weight-length (AWL) data. All smolt sampling data reflected the smolt day in which the fish were captured, and samples were not mixed between days. Smolts were collected throughout the night's migration and held in an instream live box. Forty smolts were then randomly collected from the live box, anesthetized with Tricaine methanesulfonate (MS-222), and sampled for AWL data, and the remaining smolts were released downstream from the traps.

Fork length was measured to the nearest 1 mm, and each smolt weighed to the nearest 0.1 g. Scales were removed from the preferred area (INPFC 1963) and mounted on a microscope slide for age determination. Fin clips were collected from all AWL-sampled fish for genetic analysis and stored in ethanol following ADF&G protocol (Finkle 2007b; Appendix A1).

After sampling, fish were held in aerated water until they completely recovered from the anesthetic, and were released downstream from the traps upon revival. Age was estimated from scales under 60X magnification and described using the European notation (Koo 1962).

Condition factor (Bagenal and Tesch 1978), which is a quantitative measure of the isometric growth of a fish, was determined for each smolt sampled using:

$$K = \frac{W}{L^3} 10^5 , \tag{13}$$

where K is smolt condition factor, W is weight in g, and L is FL in mm.

CLIMATE AND HYDROLOGY

Trap RPM, water depth (cm), air and water temperature (°C), estimated cloud cover (%), estimated wind velocity (mph) and wind direction were recorded daily at 1200 hours.

MARINE SURVIVAL ESTIMATES AND FUTURE RUN FORECASTING

Estimates of smolt abundance, by age, were paired with corresponding adult returns from the respective smolt year. The total return to the Chignik River watershed was calculated by adding the total Chignik River sockeye salmon escapement, the total harvest from the Chignik Management Area, and a portion of the sockeye salmon catch from the Southeastern District Mainland (SEDM) of the Alaska Peninsula Management Area and the Cape Igvak Section of the Kodiak Management Area (5 AAC 09.360(g); 5 AAC 18.360(d)). Marine survival, by age, and the number of smolts produced per spawner from their respective brood years (BYs) were also calculated.

Simple linear regression relationships were explored between smolt abundance estimates and the corresponding adult returns, by both emigration and brood years, to investigate the potential of using smolt emigration estimates to forecast future adult sockeye salmon runs. Standard regression diagnostic techniques were used to indicate violations of model assumptions. Regressions were developed between individual freshwater age classes and their corresponding adult returns (by ocean age).

A statistically significant simple regression relationship was used to forecast the saltwater-age-3 (3-ocean) component (historically, about 85% of the entire run) of the 2010 adult sockeye salmon run from the age-2. smolt emigration data, using data from 1994 through 2005. The adult return estimates for the 3-ocean age class were expanded to account for the total run from their historical proportion of the total run.

LIMNOLOGY

One limnology sampling station was set on Black Lake (Figure 3), and four sampling stations were established on Chignik Lake (Figure 3). Sampling occurred monthly from May to August (Table 1). Each station's location was logged with a global positioning system (GPS) and Chignik Lake stations marked with a buoy. The station on Black Lake was too shallow to necessitate marking with a buoy. Zooplankton samples and temperature, dissolved oxygen, and light penetration data were gathered at all four Chignik Lake stations but only stations 2 and 4 were dedicated to the collection of water samples, at 1-m and 29-m depths. Sampling was conducted following protocols established by Finkle and Bouwens (2001). Water and zooplankton were sampled once every four weeks.

Dissolved Oxygen, Light, and Temperature

Water temperature (°C) and dissolved oxygen (mg/L) levels were measured with a YSI Y-52 meter. Readings were recorded at half-meter intervals to a depth of 5 m, and then intervals increased to one meter. Upon reaching a depth of 20 m, the intervals increased to every five meters. A mercury thermometer was used to ensure the meter's calibration. Measurements of photosynthetically active wavelengths (kLux) were taken with a Li-Cor LI-250A photometer. Readings began above the surface, at the surface, and proceeded at half-meter intervals until reaching a depth of 5 m. Readings were then recorded at one-meter intervals until the lake bottom or 0 kLux light penetration (the mean euphotic zone depth, EZD; Koenings et al. 1987) was reached. The EZD for each lake was incorporated into a model for estimating sockeye salmon fry production (Koenings and Kyle 1997). One-meter temperature and dissolved oxygen measurements were compared to assess the physical conditions in the euphotic zones of each lake. Secchi disc readings were collected from each station to measure water transparency. The depths at which the disc disappeared when lowered into the water column and reappeared when raised in the water column were recorded and averaged.

Water Sampling

Seven to eight liters of water were collected with a Van Dorn bottle from the epilimnion (depth of 1 m) of both lakes and from the hypolimnion (depth of 29 m) of Chignik Lake. Water sampling and processing techniques have been consistent since 2000; for further details see Finkle, 2007a. Water analyses were performed at the Chignik weir for pH and alkalinity and at the ADF&G Near Island laboratory for total phosphorous (TP), total ammonia (TA), nitrate + nitrite, chlorophyll *a* and phaeophytin *a*. All laboratory analyses adhered to the methods of Koenings et al. (1987) and Thomsen et al. (2002). Total Kjeldahl nitrogen (TKN) was processed by the Olsen Biochemistry Lab at South Dakota State University.

Zooplankton

One vertical zooplankton tow was made at each limnology station with a 0.2-m diameter, 153-micron net from one meter above the lake bottom to the surface. One sample was placed in a 125-ml poly bottle containing 12.5 ml of concentrated formalin to yield a 10% buffered formalin solution. Samples were stored for analysis at the ADF&G Near Island laboratory. Subsamples of zooplankton were keyed to family or genus and counted on a Sedgewick-Rafter counting slide. This process was replicated three times per sample then counts were averaged and extrapolated over the entire sample. For each plankton tow, mean length (±0.01 mm) was measured for each family or genus with a sample size derived from a student's t-test to achieve a confidence level of 95% (Edmundson et al. 1994). Biomass was calculated via species-specific linear regression equations between weight and unweighted and weighted length measurements (Koenings et al. 1987).

RESULTS

TRAPPING EFFORT

Both traps were in place for a total of 63 days beginning on the smolt dates of May 6 and ending on July 7 (Appendix B1). The duration of the 2009 trapping season was 1 day longer than the 2008 season. Bad weather precluded the installation of the traps prior to May 6.

TRAP CATCH

A total of 33,889 sockeye salmon smolts were captured in the traps in 2009 (Appendix B1). In addition to sockeye salmon smolt, 7,766 sockeye salmon fry, 391 juvenile coho salmon, 145 juvenile Chinook salmon, 236 Dolly Varden char, 19,132 stickleback, 39 sculpin, 12 starry flounders, 327 pond smelt, 8 pygmy whitefish, and 13 isopods were captured (Appendix B1). The small screw trap caught 14.4% of the sockeye salmon smolts (Appendix C1).

SMOLT EMIGRATION TIMING AND POPULATION ESTIMATES

When traps were installed on May 6, the smolt emigration had already begun, with 1,966 smolts captured on May 6th. As described in the methods, smolt counts from May 6 to May 15 were used to extrapolate the estimated number of smolt that emigrated for the 9 days preceding trap installation, from April 27 to May 5. Autocorrelation tests indicated there was no autocorrelation in the data. An additional 899,144 sockeye salmon smolts were added to the cumulative season emigration estimation. Time series analysis using the first 10 days of smolt counts provided an estimate of the smolt population that may have emigrated downstream before the traps were installed. This estimate should be viewed with less confidence than estimates from years when all emigrating smolts were encompassed by the dates of the smolt enumeration project.

An estimated 8,176,509 (95% CI 7,472,166-8,880,852) sockeye salmon smolts emigrated in 2009 (Table 1; Figure 4). The majority of these fish emigrated from the end of April to mid May (Table 2; Figure 5). The 2009 emigration consisted of 110,446 age-0., 3,777,572 age-1., and 4,288,491 age-2. sockeye salmon smolts (Tables 1 and 2; Figure 6). Age-1. and age-2. fish comprised the majority of the smolt emigration from late April to late May, with a greater proportion of age-0. fish observed emigrating from late May to early July (Tables 2 and 4).

TRAP EFFICIENCY ESTIMATES

Mark-recapture experiments were conducted on four occasions beginning on May 9 and ending on May 26 (Table 3; Appendix B1). A total of 8,183 smolts, approximately 24% of the total catch, were marked and released. Thirty-one smolts were recaptured and trap efficiency estimates ranged from 0.26% to 0.53% (Table 3; Appendix B1). The majority of the marked smolts were recaptured within two days of being released. Tests were not conducted after May 26th because trap catches were below the minimum sample size needed. Therefore, the efficiencies from the May 26th test were applied to all smolt emigrating afterwards (4.97% of the total emigration).

AGE, WEIGHT, AND LENGTH DATA

A total of 1,201 sockeye salmon smolts were sampled for AWL data. Over the entire season, 16.6% were age-0. (BY 08), 49.0% were age-1. (BY 07), and 34.4% were age-2. (BY 06), (Table 4). The highest proportion by age class was in late June for age-0. smolts (91% of samples), early June for age-1. smolts (75% of samples) and early May for age-2. smolts (76% of samples). Peak emigration by total number was early to mid May for both age-1. and -2. smolts. Age-0. smolt emigration timing had a bimodal peak, in late May and again in late July (Table 2).

The mean length, weight and condition factor of age-0. smolts were 53 mm, 1.4 g and 0.93 (Tables 5 and 6, Figures 7 and 8). The mean length, weight and condition factor of age-1. smolts were 79 mm, 3.8 g and 0.77 (Tables 5 and 6; Figures 7 and 8). The mean length, weight and condition factor of age-2. smolts were 80 mm, 4.0 g and 0.76 (Tables 5 and 6; Figures 7 and 8).

Length frequency histograms indicated that larger smolts (> 65 mm) composed the majority of the catch in May and smaller smolts (< 65 mm) composed the majority of the catch in June and July (Figure 9). Sockeye salmon fry < 45 mm FL were captured throughout the trapping season, but were most abundant in the first month of the study (Appendix B1).

PHYSICAL DATA

Daily measurements of river depth and velocity (based on trap RPM), along with the 2009 climate data, are reported in Appendix D1. The absolute water depth at the trap location varied from 88 to 141 cm during the season (Appendix D1 and D2). Water temperatures averaged near 3.0°C during the first few days the traps were installed (May 6 through May 7) and increased steadily throughout the season to a maximum of 10.5°C (Appendix D1 and D2). Relatively low water levels and calm winds generally characterized the 2009 season.

MARINE SURVIVAL ESTIMATES AND RUN FORECASTING

All adult sockeye salmon from BYs 1991 through 2001 and for most offspring from BY 2002 have returned to the Chignik River watershed, and the overall marine survival of smolts ranged from 6% for BY 1999 to 67% for BY 1993 (Table 7). The estimation of the 1993 and 1994 BY marine survival includes a portion of the emigration estimate from 1996, which is considered erroneous (Edwards and Bouwens 2002). When the data were presented by emigration year, however, marine survivals ranged from 5% for emigration year 2001 to 32% for emigration year 2005, with a mean survival rate of 16% (Table 8). As noted by Finkle (2007a) survival estimates from 1996 are obviously in error and have been removed from the numbers presented here.

The number of age-2. smolts was significantly correlated with the number of returning 3-ocean adult sockeye salmon, based on the simple linear regression model ($P=0.009$; $R^2=0.64$). The smolt regression model forecasted a 2009 total adult run of 1.62 million sockeye salmon, while the formal adult forecast predicted a 2009 run of 1.38 million sockeye salmon. The total 2009 was approximately 2.1 million sockeye salmon.

LIMNOLOGY

Sampling was conducted each month in both Black Lake (May 17, June 15, July 9, and August 13) and Chignik Lake (May 15, June 8, July 2, and August 12). Comparisons with historical limnological data can be found in Appendices F1 and F2.

Temperature and Dissolved Oxygen

Black Lake

The 1-m temperature in Black Lake in 2009 increased from 11.5°C on May 17, to 13.4°C on August 13 (Table 9; Figure 10). Dissolved oxygen levels at the 1-m depth increased from 8.0 to 9.4 mg/L over the same dates (Table 10; Figure 10).

Chignik Lake

The 1-m temperature in Chignik Lake increased from 5.0°C on May 15, to 11.5°C on August 12 (Table 11; Figure 11). Dissolved oxygen levels decreased from 10.3 mg/L to 9.1 mg/L over the same dates (Table 11; Figure 11). Dissolved oxygen levels were lowest in July (8.8 mg/L). Within the water column temperature and dissolved oxygen levels each remained similar throughout the season, with no more than 1.7 °C variation between surface and depth water temperatures at any point.

Light Penetration and Water Transparency

Black Lake

Light penetrated the entire water column in Black Lake during the 2009 sampling season (Table 12; Figure 12). The EZD of Black Lake exceeded its maximum depth throughout the entire sampling season. The mean lake depth (1.9 m) was used to calculate the euphotic volume (EV) of 78.1 x 10^6 m^3 (Table 12; Figure 12). During the 2009 sampling season, water transparency in Black Lake ceased at a mean depth of 1.6 m, as measured by Secchi disc.

Chignik Lake

Light penetration ceased at a depth of 8 m in May, 9 m in June, 11 m in July, and at 8 m in August. The EZD was 4.50 m in May, 7.32 m in June, 15.16 m in July, and 7.46 m in August (Table 13; Figure 12). The EV in Chignik Lake averaged 207.5 x 10^6 (Table 12) m^3, whereas water transparency in Chignik Lake ceased at a mean depth of 2.0 m as measured by Secchi disc.

Water Quality Parameters, Nutrient Levels, and Photosynthetic Pigments

Black Lake

In 2009, the pH in Black Lake averaged 7.7 and alkalinity averaged 23.5 mg/L $CaCO_3$ (Table 14) across stations and depth. Total phosphorous (TP) averaged 41.1 µg/L P and TKN averaged 233.5 µg/L N. Ammonia averaged 2.6 µg/L N and nitrate + nitrite averaged 1.3 µg/L N in 2009. Chlorophyll *a* averaged 3.0 µg/L and phaeophytin *a* had a seasonal mean of 1.4 µg/L. Chlorophyll *a,* phaeophytin *a,* and TKN all decreased from May to July, then increased again in August (Table 14).

Chignik Lake

In 2009, the pH in Chignik Lake averaged 7.5 and alkalinity averaged 22.9 mg/L $CaCO_3$ across stations and depth. TP averaged 22.3 µg/L P and TKN averaged 79.8 µg/L N. Ammonia averaged 5.8 µg/L N and nitrate + nitrite averaged 151.8 µg/L N. It should be noted that TKN steadily increased from May to August. Chlorophyll *a* averaged 2.4 µg/L and phaeophytin-*a* had a seasonal mean of 0.6 µg/L and levels were greatest in May and August (Table 15).

ZOOPLANKTON

Black Lake

Copepod abundance (seasonal average 59,188/m^2) was comparable to cladoceran abundance (seasonal average 61,417/m^2) when averaged over the sampling season in Black Lake. On average, the most prevalent identifiable stage of copepods in Black Lake were naupulii (juvenile) with a seasonal mean of 28,938/m^2. The copepod *Cyclops* was also abundant with a seasonal mean of 24,031/m^2 (Table 16; Appendix F3). *Bosmina* were the most common cladocerans in Black Lake (seasonal average 49,209/m^2) and were markedly more abundant in August than in other months (Table 16).

Copepod biomass was predominantly *Cyclops*, and was greatest in August (34.9 mg/m^2 in August, 24.0 mg/m^2 weighted seasonal average; Table 17). Similarly, cladoceran biomass, including ovigerous individuals, was predominantly composed of *Bosmina* throughout the sampling season with a weighted seasonal average of 49.5 mg/m^2 and greatest density in August (159.1 mg/m^2) (Table 17; Appendix F4). Copepod biomass was greater than cladoceran biomass in May and June, but the increase in *Bosmina* in July and August resulted in greater cladoceran biomass than copepod biomass over the sampling period (Table 17).

Average seasonal lengths of the major zooplankton in Black Lake were 0.55 mm for C*yclops*, and 0.36 mm for *Bosmina* (Table 18).

Chignik Lake

Copepod abundance (weighted seasonal average 225,277/m^2) was greater than the average weighted seasonal cladoceran abundance (80,928/m^2) (Table 19). Not including ovigerous zooplankton, *Cyclops* (130,339/m^2*)*, nauplii (48,066/m^2) and *Diaptomus* (46,038/m^2), were the most abundant genera of copepods during the season (Table 20; Appendix F5). *Cyclops* was most abundant from May to July, while *Diaptomus* and nauplii were most abundant in August (Table 19). *Daphnia* (43,643/m^2) and *Bosmina* (21,939/m^2) and were the most common cladocerans in Chignik Lake (Table 19; Appendix F5).

Copepod biomass was composed predominantly of *Cyclops* throughout the season, with the greatest density occurring in July (573.4 mg/m^2; weighted seasonal average 191.6 mg/m^2; Table 20). Cladoceran biomass was composed primarily of *Daphnia* and *Bosmina* and generally increased from May to August (Table 20). Biomass estimates of the copepod *Cyclops* were substantially greater than estimates of other copepods and cladocerans from May through July, however *Diaptomus* were predominant in August (247.9 mg/m^2; Table 20) followed by *Daphnia* (183.4 mg/m^2; Table 20). Driven by the peak in *Cyclops* density in July, the weighted seasonally averaged copepod biomass (290.1 mg/m^2) was greater than cladocerans biomass (80.5 mg/m^2) for a total weighted average of 370.6 mg/m^2 of all Chignik Lake zooplankton (Table 20; Appendix F6).

Average seasonal lengths of the major non-egg bearing zooplankton in Chignik Lake were 0.88 mm for *Diaptomu*s*,* 0.70 mm for C*yclops*, 0.60 mm for *Epischura*, 0.37 mm for *Bosmina*, and 0.53 mm for *Daphnia* (Table 21). Ovigerous zooplankton were generally longer than non-egg bearing individuals (Table 21).

DISCUSSION

SMOLT EMIGRATION TIMING AND POPULATION ESTIMATES

The point estimate of the 2009 total smolt emigration was the largest in the past 6 years (Figure 4). The point estimate of the emigrating population may be considered a conservative estimate, because population estimates inherently contain measurement and process errors. The traps were both installed on May 6, as bad weather and ice had prevented installation prior to this date. The water temperature at installation and for several days after installation was less than 3°C, which is below temperatures observed to coincide with other salmon migrations (Clark and Hirano 1995). However, the first night traps were operational, over 1,900 smolts were captured, indicating smolts were already emigrating in large numbers. Since 1996, all peak emigration days have occurred after May 2, and 9 out of 10 of the peak emigration events have occurred after May 20. In contrast, the majority of smolts in 2009 emigrated before May 20, and emigration timing was similar to 2001, when the peak emigration occurred between April 29 and May 10. Approximately 11.0% of the total estimated sockeye salmon emigration had passed by the trap installation date due to the early-run timing in 2009. Although the confidence in the smolt emigration estimate is fair, the accuracy of the estimate should be considered less precise than those in years when the traps were operational from emigration commencement to finish.

The point estimate may also be considered conservative due to possible trap avoidance by large smolt. Age-1. smolt, in particular, were longer and heavier than in all years except 2007 (Table 6). These larger smolts might have been able to avoid the trap in 2007, thereby biasing the population estimate low (Finkle 2007a). A smolt enumeration project on Bear Lake, located on the north side of the Alaska Peninsula, in 2001, also demonstrated rotary screw trap avoidance by large (>70mm) sockeye salmon smolts (Bouwens 2001). Unlike Chignik River, Bear River is shallow, but trap avoidance demonstrated at that site suggests population estimates may be biased low in years with an abundance of large-sized smolts. However, mark-recapture experiments in the Chignik River met the assumptions of the mark-recapture model (Carlson et al. 1998) and the Chignik River project continued beyond the end of the smolt emigration.

Despite the need to calculate the early portion of the emigration, the confidence in the 2009 estimate is fair considering mark-recapture experiment results were similar to those from past years, sample sizes achieved or exceeded the number required to reduce estimate bias (Carlson et al. 1998), and time-series plots of the estimated emigration timing are comparable to other years. However, consistently low emigration numbers prevented mark-recapture experiments after May 26, precluding further refinement of trap efficiency estimates. The 2009 trap efficiency (0.4%) was similar to 2007 (0.4%), 2004 (0.8%), and 2006 (0.6%) estimates. The low trap efficiency estimates are reasonable considering multiple factors: 1) the cross-sectional area of the Chignik River is roughly 106 m^2 at the trap location and the traps fished approximately 3.0% (2.75 m^2) of the Chignik River, 2) delayed mortality and mark-retention trials did not indicate the need to adjust trap efficiency or population estimates, and 3) the mark-recapture events possessed adequate sample sizes to minimize bias of the population estimate.

AGE STRUCTURE OF THE 2009 EMIGRATION AND MARINE SURVIVAL

The large size and increased proportion of age-1. and age-2. smolts in 2009 may be attributable to several years of targeting the lower end of escapement goals for sockeye salmon returning to the Chignik watershed. Historically, the Chignik River smolt emigration was composed of a majority of age-1. smolts, with the remainder mostly age-2. fish. In recent years, an increased proportion of age-0. smolts had been observed and small young-of-the-year sockeye salmon have been captured in large numbers in the Chignik River and Chignik Lagoon (Finkle and Ruhl 2008). In 2009, however, fewer age-0. smolts were captured in the trap (1.4%) than in 2005–2008 (19%-23%) (Appendix E1). Under stressful environmental conditions, such as elevated temperatures and poor visibility, underyearling sockeye salmon may successfully migrate to sea (Rice et al. 1994). The lack of age-0. emigrating fish in 2009 may suggest that freshwater rearing conditions were improved in 2009, allowing fish to remain in the watershed to overwinter. Since 2003, managers have attempted to target the lower bounds of the escapement goal for both runs, in order to reduce competition for resources and allow the available zooplankton forage base to increase under reduced top-down grazing pressure from rearing sockeye salmon (Finkle 2007a). Decreased competition among juveniles for food may be allowing juveniles to successfully grow, rear and overwinter in the lakes rather than migrate to the marine environment early.

Survivals by age class fluctuate, ranging from 5% (age-1. from 2001 BY) to 48% (age-2. from 2003 BY) (Table 9). Marine survivals of Chignik sockeye salmon smolts by fully recruited emigration year (excluding 1996), are well within the ranges observed in other Alaskan sockeye systems (Burgner 1991; Bradford 1995). This estimated variability in marine survival implies that given constant freshwater production, adult returns would still fluctuate because of annual differences in productivity of the marine environment.

ZOOPLANKTON ABUNDANCE AND SPECIES COMPOSITION

Zooplankton densities in both Black and Chignik lakes were high compared to recent years, and followed historical patterns of seasonal population abundance. Zooplankton density in Black Lake is historically predominated by copepods early in the season, decreasing throughout the summer then peaking in late July or August (Finkle and Ruhl 2008). Cladoceran densities become the predominant zooplankton in Black Lake late in the summer, after increasing steadily throughout the season with population densities peaking in August when phytoplankton levels increased and many of the zooplanktivorous fish have left the lake. This pattern was seen in 2009, and seasonal averages of both copepod and cladoceran densities were greater in 2009 than in the previous 4 years, with copepod *Cyclops* predominating copepod biomass (although copepod nauplii were also present in high numbers) and *Bosmina* the predominant cladoceran. The average monthly weighted biomass of cladocerans in Black Lake was extremely high relative to recent years. Since cladocerans are a preferred food source for juvenile sockeye salmon, their abundance may be a better indicator of potential juvenile sockeye salmon production (Koenings et al. 1987; Kyle 1992).

Chignik Lake zooplankton populations historically follow a pattern similar to Black Lake zooplankton populations, but copepods dominate the zooplankton population even in late season when overall zooplankton densities are greatest. Chignik Lake copepod populations historically are comprised primarily of *Cyclops*, while the most abundant cladoceran is *Bosmina*. In 2007 and 2009, however, the most abundant cladoceran was *Daphnia*. *Daphnia* is an important primary prey item for juvenile sockeye salmon (Kyle 1996; Honnold and Schrof 2001) and may be a more important indicator of lake forage activity than *Bosmina*, which are smaller and therefore may be more difficult for juvenile sockeye salmon to locate and eat. The collection of zooplankton samples in August are important for accurate seasonal average comparisons, because cladoceran abundance may not peak until late July or mid August, and therefore would not be represented in samples collected earlier in the season.

The zooplankton communities in both Black and Chignik lakes experience top-down pressures exerted by planktivorous fishes (Kyle 1992; Stockner and MacIsaac 1996). Evidence of overgrazed zooplankton populations can be reflected by reductions in zooplankton length and shifts in species composition (Kyle 1992; Schindler 1992). The continued observed trend of inseason zooplankton composition changes and density fluctuations are indicative of top-down grazing pressure on zooplankton, as the emigration of sockeye salmon juveniles from Black Lake in July and August corresponded to the greatest overall zooplankton densities, and greatest number of *Bosmina* in zooplankton samples. This *Bosmina* spike coincides with the migration of Black Lake juvenile sockeye salmon to Chignik Lake, which suggests that the impact and magnitude of top-down pressures are greater than bottom-up pressures in Black Lake as biomass increases with a reduction in grazing pressure. Mean length of *Bosmina* throughout the season also indicates top-down grazing pressures. Mean length decreased from 0.40 mm to 0.33 mm from May to August, below the minimum elective feeding threshold of 0.40 mm for juvenile sockeye salmon (Kyle 1992), indicating that top-down grazing pressures were removing larger *Bosmina* from the system. Finally, the observed inseason composition changes suggest top-down limitations occurred because the nutrients that drove primary production, chlorophyll *a* and phaeophytin *a*, fluctuated minimally over the 2009 sampling season.

Juveniles rearing in the watershed from 2004 to 2006 may have been stressed by resource limitation, including competition for zooplankton, and increased temperatures and turbidity, and left the system as age-0. fish, as observed in smolt trap catches from 2005, 2006, and 2008. Targeting the lower end of the escapement goals since 2003 may have successfully reduced foraging competition among juveniles, allowing for more efficient feeding as zooplankton levels recovered from years of over-grazing. In 2009, few age-0. fish were observed in the traps, suggesting these fish may be remaining in the watershed to overwinter before emigrating as age-1. smolt. Similar proportions of age classes in the 2010 emigration will be a positive indicator that rearing conditions in the Chignik watershed are improving from those observed from 2003 to 2007.

LIMNOLOGY

Water temperatures in Chignik and Black lakes were cooler than in most recent years. The Alaska Peninsula, however, as indicated by annual monthly temperatures at Cold Bay from 1961 to 2009 (ACRC 2009), is generally experiencing warmer temperatures. Chignik Lake monthly 1-m and 29-m temperatures in 2009 were cooler than all years since 2000 other than 2008 and the water column less stratified. Black Lake monthly temperatures in 2009 were warmer than in 2007 and 2008, but cooler than all other years since 2001. Black Lake is a shallow lake, heavily influenced by wind mixing, which can affect both water temperature and clarity. Although both lakes were more turbid in 2009 than in the previous 5 seasons, both lakes have shown a general pattern of decreasing turbidity since 1991, which should provide better feeding conditions for both juvenile fishes and zooplankton. Cooler temperatures and increased water clarity would provide less metabolically taxing conditions for juveniles, and allow young-of-the-year sockeye salmon to successfully remain in the watershed for overwintering, rather than emigrate as age-0. fish.

Nutrient data can indicate limitations in aquatic environments. A comparison of total nitrogen (TN) to total phosphorous (TP) is a simple indicator of aquatic ecosystem health, because both are necessary for primary production (Wetzel 1983; UF 2000). Nitrogen-phosphorous ratios of less than 10:1 indicate nitrogen limitations (USEPA 2000). Based on the 2009 water quality data, nutrient levels in both lakes fell into low production (oligotrophic) levels as defined by several trophic state indices (Carlson 1977; Forsberg and Ryding 1980, Carlson and Simpson 1996) but were comparable to other Alaskan lakes (Honnold et al. 1996; Schrof and Honnold 2003). Seasonally averaged TN:TP ratios for Black Lake were 5.6:1, and decreased throughout the summer season. Similarly, although Chignik Lake ratios were more constant, the seasonal average was 3.5:1. This average is comparable to most years in Chignik Lake, with the exception of 2007, 2005, 2004, and 2000 which had high TN:TP ratios. Black Lake TN:TP ratios were low when compared to the 2002–2009 average (9.2:1). Exceptions occurred in 2003 (6.1:1) and 2007 (5.1:1).

The quantity of photopigments present in an aquatic system is related to the biomass of producers and potential production level of the system. The ratio of chlorophyll *a* (associated with active cells) to phaeophytin *a* (a degradation product associated with senescent or dead cells) serves as an indicator of the physiological condition of the algal community. High chlorophyll *a* to phaetophyin *a* ratios indicate chlorophyll *a* is available for photosynthesis, and algal levels are adequate for supporting primary consumption. Conversely, low ratios may suggest that primary productivity is taxed. A comparison of the photosynthetic pigment, chlorophyll *a,* to its byproduct, phaeophytin *a,* showed that chlorophyll *a* concentrations were proportionally high in both lakes (seasonal mean of 4.2 chlorophyll *a* to 1 phaeophytin *a* in Chignik Lake and 2.6 chlorophyll *a* to 1 phaeophytin *a* in Black Lake). This indicated that the potential for rapid algal (phytoplankton) growth existed throughout the season because chlorophyll *a* was readily available for photosynthesis (COLAP 2001). From 2000 to 2002, ratios were low (0.3 to 1.8) in Black Lake but have increased since 2004 (2004–2009 average: 4.1 chlorophyll *a* to 1 phaeophytin *a*). This suggests the primary productivity capacity of Black Lake may have improved. Chlorophyll *a* and phaeophtin *a* were both highest in Chignik Lake in May and again in August, while levels were more variable in Black Lake throughout the season, peaking in August. Changes in nutrients and forage bases can significantly impact higher trophic levels such as secondary or tertiary consumers (Kyle et al. 1988; Milovskaya et al. 1998). For the Chignik watershed, these negative changes could cause migratory behavior or decreased juvenile sockeye salmon freshwater survival (Parr 1972; Ruggerone 1994; Bouwens and Finkle 2003). Thus, it is important to know and understand patterns of resource abundance and habitat usage in the watershed if the carrying capacities for each lake are to be estimated.

The seasonal pH levels in Black and Chignik lakes remained consistent with observations from 2007 and 2008; slightly higher than seasonal averages from the 1960s (1960s Black Lake seasonal average pH = 7.42; 1960s Chignik Lake seasonal average pH = 7.27; Narver 1966), and from 2000 to 2003, but lower than those measured from 2004 to 2006. pH levels were slightly lower in 2009 compared to 2004–2006 and zooplankton densities were greater than 2006–2008. The current levels are well within a safe pH range of roughly 4.5 to 9.5 (Wetzel 1983). Higher pH in 2004–2006 may have been the result of predation on zooplankton from increased densities of juvenile fish, which in turn resulted in increased phytoplankton production. The decreased grazing pressure by zooplankton allows phytoplankton biomass to increase and remove greater quantities of carbon dioxide from the water through photosynthesis, increasing the overall level of pH in each lake.

OVERWINTERING AND LAGOON UTILIZATION

The continued collection of smolt emigration data also aids in investigation into changes in life history strategies in the Chignik watershed caused by changes in ecosystem dynamics, such as those seen in Black Lake. Reductions in Black Lake water volume and rearing habitat have occurred simultaneously with warmer water temperatures since the 1970s. Timing of Black Lake emigration has shifted earlier in the summer relative to 1970s timing (Westley et al. 2008). The early emigration seen in 2009 may be reflective of this consistently earlier seasonal timing. Chignik Lake species composition has shifted since the 1960s (Westley et al. 2009) to encompass a greater diversity and more even proportions of non-sockeye species, and competition between Black Lake emigrants and Chignik Lake smolts has been demonstrated (Parr 1972; Ruggerone 2003). It has been suggested Chignik Lagoon may serve as a rearing ground for juvenile sockeye salmon seeking refuge from rearing limitations in the watershed (Simmons 2009). Underyearling (age 0.) sockeye salmon have been observed to migrate from limited lake-rearing habitats and survive in marine conditions (Rice et al. 1994). As early as the 1960s, studies indicated that juvenile sockeye salmon may move from Chignik Lake to Chignik Lagoon (Phinney 1968). Simmons (2009) found that sockeye salmon fry and smolts were abundant in Chignik Lagoon throughout the summer, and that residency time was closely related to sockeye salmon length and age, with younger (age 0. and age 1.), smaller fish remaining longer in the lagoon to achieve additional growth in body size before their migration to the marine environment.

Top-down pressures on the Chignik Lake zooplankton community, as demonstrated by the seasonal regulation of cladoceran size, for example, are caused by over-grazing from rearing sockeye salmon, and likely due to the downstream migration of Black Lake juveniles and increased utilization of Chignik Lake resources. Chignik Lagoon provides a forage base of amphipods, pericardians, and other small crustacean taxa, which may alleviate some of the top-down pressure in Chignik Lake (Bouwens and Finkle 2003). In a system with variable and limiting freshwater conditions such as those seen in the Chignik watershed, Chignik Lagoon may provide the best opportunity for additional growth for emigrating juvenile sockeye (Simmons 2009). Additionally, juvenile sockeye salmon were observed to migrate upstream from Chignik Lagoon to Chignik Lake as age-0. fish and emigrate to sea the following spring (Iverson 1966). However, no effort to study upstream migration of smolts have been made in recent years, and therefore it is uncertain what proportion of these pre-smolt sockeye salmon go to sea, continue to rear in the lagoon, or return to rear and overwinter in Chignik Lake. Although the rearing and migratory behavior of juvenile sockeye salmon in Chignik Lagoon is not completely understood, these data do suggest that as rearing habitat in Black Lake continues to decrease, the lagoon may provide an important rearing habitat for juvenile sockeye salmon continuing to the marine environment.

FORECASTS OF ADULT SALMON RETURNS

A formal forecast for the 2010 adult run was prepared which predicted specific age classes based on sibling ocean age-class relationships and temperature indices when possible, and median values when sibling relationships did not exist. Using these sibling methods, the 2010 Chignik sockeye salmon forecast is 2.2 million (Eggers et al. 2010).

A smolt-based forecast has also been developed annually since 2002. Since its inception, the smolt-based forecast has overestimated the actual total sockeye salmon adult return to the Chignik watershed by as much as 107% (2004 forecast) and underestimated it by as little as 9% (2003 forecast). Forecast methods have included simple and multiple linear regressions of smolt outmigrants by age class to ocean-age class adult returns and multiple regressions of outmigrant-age class smolts and temperature against ocean-age class adult returns. The simple linear regression smolt forecast relationship for the 2009 adult return underestimated the adult return by 22%. The simple linear regression employed in the 2009 smolt forecast explained a high percent (64%) of the variability of the dependent variable (adult returns), as explained by the independent variable (smolt outmigrants). Forecast accuracy varies annually, with no clear pattern of under- or over-forecasting by either sibling temperature relationships or smolt linear regression techniques.

For 2010 forecasting purposes, the emigration during 1996 was excluded from the analysis because adult return and marine survival data indicated that the emigration was likely underestimated (Edwards and Bouwens 2002). A simple regression model was developed to forecast the 2010 adult run using smolt emigration data. The regression relationship using outmigrant age-2. smolts and 3-ocean adult returns was statistically significant ($P = 0.009$) and accounted for 82% of the total return. The 2010 smolt-based forecast of 1.54 million sockeye salmon is approximately 650,000 fewer fish than was forecasted using adult sibling and temperature regression relationships.

The smolt forecasting method does not have the resolution to forecast by run because we have not yet determined the stock-of-origin of the smolts. However, current genetic analyses may provide a basis for Chignik sockeye salmon smolt stock separation. Genetic samples collected in 2006–2008 are currently being analyzed by a graduate student, and 2009 samples were collected and stored. Genetic analyses of the Chignik sockeye salmon smolt emigration lend themselves to stock-based smolt forecasts in addition to providing information on stock-specific life history traits of rearing and emigrating juveniles.

Additionally, a presentation describing the sockeye salmon life cycle and the Chignik Sockeye Salmon Smolt Enumeration project was given to students attending the Chignik Lake School on May 9. The goal of the presentation was to relay the value of the smolt project and foster stewardship in students for their resource and to help them learn about resource sustainability. A student internship involving two Chignik Lake high school students and one young adult participant also took place in June and July, 2009. By actively promoting community youth involvement, it is hoped the smolt project can foster a sense of inclusion in the many research and management projects the department oversees in the Chignik watershed.

CONCLUSION

ADF&G has conducted the smolt enumeration project since 1994, and in 2008 incorporated the collection of valuable limnological samples from both lakes. When smolt enumeration and limnological data are combined, they provide a means to investigate life history changes in emigrating juvenile sockeye salmon, levels of primary and secondary production, and watershed health as an indicator of habitat available for rearing salmon. These data have proven instrumental for enhancing management of the system, such as targeting the lower ends of the escapement goals in light of overescapement and decreased rearing habitat in Black Lake. Genetic samples collected from emigrating sockeye salmon smolts will also provide a better understanding of ecological events in the watershed. Data from this project are essential for monitoring the health of sockeye salmon in Chignik River watershed, because smolt emigration information may be the only available means to link changes in run strength to freshwater or marine influences, or to climate changes.

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TABLES AND FIGURES

Table 1.–Chignik River sockeye salmon smolt population estimates, by age class, 1994 to 2009.

Year		Number of Smolt							95% C.I.	
		Age-0.	Age-1.	Age-2.	Age-3.	Age-4.	Total	S.E.	Lower	Upper
1994	Numbers	0	7,263,054	4,270,636	0	0	11,533,690	1,332,321	8,922,341	14,145,038
	Percent	0.0	63.0	37.0	0.0	0.0	100.0			
1995	Numbers	735,916	2,843,222	5,178,450	0	0	8,757,588	1,753,022	5,321,664	12,193,512
	Percent	8.4	32.5	59.1	0.0	0.0	100.0			
1996	Numbers	80,245	1,200,793	731,099	5,018	0	2,017,155	318,522	1,392,852	2,641,459
	Percent	4.0	59.5	36.2	0.2	0.0	100.0			
1997	Numbers	528,846	11,172,150	13,738,356	122,289	0	25,561,641	2,962,497	19,755,145	31,368,136
	Percent	2.1	43.7	53.7	0.5	0.0	100.0			
1998	Numbers	75,560	5,790,587	20,374,245	158,056	0	26,398,448	3,834,506	18,882,817	33,914,080
	Percent	0.3	21.9	77.2	0.6	0.0	100.0			
1999	Numbers	73,364	12,705,935	8,221,631	78,798	0	21,079,728	3,070,060	15,062,412	27,097,045
	Percent	0.3	60.3	39.0	0.4	0.0	100.0			
2000	Numbers	1,270,101	8,047,526	4,645,121	160,017	0	14,122,765	1,924,922	10,349,918	17,895,611
	Percent	9.0	57.0	32.9	1.1	0.0	100.0			
2001	Numbers	521,546	18,940,752	5,024,666	516,723	5,671	25,009,358	5,042,604	15,125,854	34,892,862
	Percent	2.1	75.7	20.1	2.1	0.0	100.0			
2002	Numbers	440,947	13,980,423	2,223,996	72,184	0	16,717,551	2,112,220	12,577,007	20,856,909
	Percent	2.6	83.6	13.3	0.4	0.0	100.0			
2003	Numbers	155,047	5,146,278	1,449,494	0	0	6,750,819	527,041	5,717,820	7,783,819
	Percent	2.3	76.2	21.5	0.0	0.0	100.0			
2004	Numbers	244,206	6,172,902	2,239,716	0	0	8,656,824	1,219,278	6,267,039	11,046,609
	Percent	2.8	71.3	25.9	0.0	0.0	100.0			

- continued -

Table 1.–Page 2 of 2.

Year		Number of Smolt							95% C.I.	
		Age-0.	Age-1.	Age-2.	Age-3.	Age-4.	Total	S.E.	Lower	Upper
2005	Numbers	859,211	2,075,681	1,468,208	32,889	0	4,435,988	1,034,892	2,407,600	6,464,376
	Percent	19.4	46.8	33.1	0.7	0.0	100.0			
2006	Numbers	1,744,370	2,849,043	2,847,624	119,614	0	7,560,651	2,280,536	3,090,799	12,030,502
	Percent	23.1	37.7	37.7	1.6	0.0	100.0			
2007	Numbers	9,286	1,926,682	1,028,865	0	0	2,964,833	969,567	1,064,482	4,865,184
	Percent	0.6	74.4	25.0	0.0	0.0	100.0			
2008	Numbers	1,017,498	3,309,894	987,928	41,136	0	5,356,455	605,266	4,170,134	6,542,777
	Percent	19.0	61.8	18.4	0.8	0.0	100.0			
2009	Numbers	110,446	3,777,572	4,288,491	0	0	8,176,509	320,013	7,472,166	8,880,852
	Percent	1.4	46.2	52.4	0.0	0.0	100			

Table 2.–Estimated sockeye salmon smolt emigration from the Chignik River in 2009 by age class and statistical week.

Statistical Week	Starting Date[a]	Number of Smolt			
		age-0.	age-1.	age-2.	Total
17	4/19	0	4,562	14,290	18,852
18	4/26	0	68,635	214,979	283,614
19	5/3	0	668,132	2,092,746	2,760,878
20	5/10	0	1,826,023	1,295,384	3,121,407
21	5/17	5,207	694,628	341,586	1,041,421
22	5/24	41,417	414,909	283,262	739,588
23	5/31	1,909	62,072	19,003	82,984
24	6/7	1,667	13,982	15,217	30,866
25	6/14	10,309	15,910	9,453	35,673
26	6/21	4,803	4,304	1,520	10,626
27	6/28	39,567	3,151	1,050	43,769
28	7/5	5,567	1,264	0	6,831
Total		110,446	3,777,572	4,288,491	8,176,509

[a] Smolt outmigration prior to 5/6 is estimated

Table 3.–Results from mark-recapture tests performed on sockeye salmon smolt migrating through the Chignik River, 2009.

Date	No. Marked	Total Recaptures	Trap Efficiency[a]
5/9	3,217	16	0.53%
5/16	2,940	10	0.37%
5/21	762	1	0.26%
5/26	1,264	4	0.40%
Total	8,183	31	0.38%

[a] Calculated by: E = {(R+1)/(M+1)}*100 where: R = number of marked fish recaptured, and; M = number of marked fish (Carlson et al. 1998).

Table 4.–Estimated age composition of Chignik River sockeye salmon smolt samples in 2009 by week.

Stat Week	Starting Date		Number of Smolt Age-0.	Age-1.	Age-2.	Age-3.	Total
19	5/3	Percent	0	24.2	75.8	0	100.0
		Numbers	0	29	91	0	120
20	5/10	Percent	0	58.5	41.5	0	100.0
		Numbers	0	117	83	0	200
21	5/17	Percent	0.5	66.7	32.8	0	100.0
		Numbers	1	132	65	0	198
22	5/24	Percent	5.6	56.1	38.3	0	100.0
		Numbers	11	111	76	0	198
23	5/31	Percent	2.3	74.8	22.9	0	100.0
		Numbers	3	98	30	0	131
24	6/7	Percent	0.0	45.4	0.1	0	100.0
		Numbers	4	34	37	0	75
25	6/14	Percent	28.9	44.6	26.5	0	100.0
		Numbers	24	37	22	0	83
26	6/21	Percent	45.2	40.5	14.3	0	100.0
		Numbers	19	17	6	0	42
27	6/28	Percent	90.5	0.0	0.0	0	100.0
		Numbers	115	9	3	0	127
28	7/5	Percent	81.5	18.5	0	0	100.0
		Numbers	22	5	0	0	27
Total	1,201	Percent	16.6	49	34.4	0	100.0
		Numbers	199	589	413	0	1,201

Table 5.–Length, weight, and condition factor of Chignik River sockeye salmon smolt samples in 2009, by age and statistical week.

				Length (mm)		Weight (g)		Condition Factor	
Age	Stat Week	Starting Date	Sample Size	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
0	21	5/17	1	49	0.00	0.7	0.00	0.59	0.00
0	22	5/24	11	49	0.72	0.9	0.06	0.74	0.04
0	23	5/31	3	52	2.67	1.0	0.00	0.96	0.00
0	24	6/7	4	56	3.84	1.5	0.31	0.81	0.04
0	25	6/14	23	50	0.98	1.2	0.07	0.96	0.02
0	26	6/21	19	50	1.10	1.2	0.09	0.96	0.03
0	27	6/28	115	54	0.54	1.5	0.05	0.93	0.01
0	28	7/5	22	52	0.83	1.3	0.08	0.93	0.03
Total			198	53	0.39	1.4	0.04	0.93	0.01
1	19	5/3	29	81	0.99	3.9	0.16	0.73	0.01
1	20	5/10	117	79	0.43	3.6	0.06	0.72	0.01
1	21	5/17	132	75	0.34	3.2	0.05	0.76	0.01
1	22	5/24	111	78	0.60	3.5	0.13	0.72	0.01
1	23	5/31	98	91	1.64	5.5	0.38	0.78	0.01
1	24	6/7	34	82	1.70	5.2	0.43	0.90	0.01
1	25	6/14	36	71	2.04	3.5	0.26	0.91	0.02
1	26	6/21	17	68	2.40	3.0	0.32	0.92	0.02
1	27	6/28	9	69	3.14	3.2	0.39	0.96	0.04
1	28	7/5	5	66	4.43	3.2	0.61	1.03	0.05
Total			588	79	0.45	3.8	0.08	0.77	0.00
2	19	5/3	91	79	0.35	3.5	0.05	0.72	0.01
2	20	5/10	83	80	0.52	3.6	0.07	0.71	0.01
2	21	5/17	65	78	0.54	3.6	0.09	0.76	0.01
2	22	5/24	76	80	0.79	3.9	0.20	0.74	0.01
2	23	5/31	30	86	2.37	4.6	0.10	0.78	0.01
2	24	6/7	37	85	0.48	5.2	0.11	0.86	0.01
2	25	6/14	22	83	0.85	5.2	0.13	0.89	0.01
2	26	6/21	6	82	2.36	4.9	0.23	0.91	0.06
2	27	6/28	3	87	2.19	5.4	0.53	0.83	0.02
2	28	7/5	0						
Total			413	80	0.31	4.0	0.05	0.76	0.00

Table 6.–Mean length, weight, and condition factor of sockeye salmon smolt samples from the Chignik River, year and age, 1994–2009.

		Length (mm)			Weight (g)			Condition Factor		
		Sample		Standard	Sample		Standard	Sample		Standard
Year	Age	Size	Mean	Error	Size	Mean	Error	Size	Mean	Error
1995	0	272	46	0.18	272	0.7	0.01	272	0.74	0.01
1996	0	125	49	0.45	113	1.0	0.03	113	0.82	0.01
1997	0	195	46	0.22	195	0.8	0.01	195	0.83	0.01
1998	0	15	45	0.96	15	0.7	0.03	15	0.73	0.03
1999	0	40	52	0.79	40	1.3	0.06	40	0.97	0.03
2000	0	223	60	0.52	223	2.1	0.05	223	0.91	0.01
2001	0	96	56	0.51	96	1.5	0.04	96	0.88	0.01
2002	0	217	49	0.27	217	1.2	0.02	217	0.98	0.01
2003	0	149	56	0.53	149	1.5	0.05	149	0.79	0.01
2004	0	347	56	0.44	347	1.7	0.05	347	0.91	0.01
2005	0	652	56	0.28	649	1.5	0.03	649	0.83	0.01
2006	0	427	52	0.24	427	1.0	0.02	427	0.70	0.01
2007	0	6	64	2.47	6	2.5	0.08	6	1.03	0.16
2008	0	568	53	0.17	566	1.1	0.01	566	0.76	0.01
2009	0	198	53	0.39	196	1.4	0.04	196	0.93	0.01
1994	1	1,715	67	0.16	1,706	2.3	0.02	1,706	0.75	0.00
1995	1	1,272	60	0.34	1,272	2.0	0.04	1,272	0.82	0.00
1996	1	1,423	68	0.29	1,356	2.7	0.04	1,356	0.81	0.00
1997	1	1,673	63	0.35	1,673	2.4	0.04	1,673	0.81	0.00
1998	1	785	69	0.38	780	2.7	0.06	780	0.78	0.01
1999	1	1,344	77	0.17	1,344	4.1	0.03	1,344	0.89	0.00
2000	1	1,175	72	0.22	1,175	3.3	0.04	1,175	0.86	0.00
2001	1	1,647	65	0.13	1,647	2.1	0.02	1,647	0.76	0.00
2002	1	1,588	65	0.18	1,588	2.3	0.02	1,588	0.83	0.00
2003	1	1,665	65	0.11	1,665	2.1	0.01	1,665	0.75	0.00
2004	1	1,030	69	0.20	1,030	2.8	0.03	1,030	0.83	0.00
2005	1	892	69	0.25	892	2.7	0.03	892	0.81	0.00
2006	1	662	68	0.28	662	2.4	0.03	662	0.76	0.00
2007	1	809	82	0.16	809	4.9	0.03	809	0.88	0.00
2008	1	844	65	0.17	817	2.1	0.02	817	0.76	0.00
2009	1	588	79	0.45	571	3.8	0.08	571	0.77	0.00
1994	2	1,091	77	0.22	1,068	3.6	0.04	1,068	0.74	0.00
1995	2	1,008	75	0.23	1,008	3.5	0.04	1,008	0.80	0.00
1996	2	548	80	0.34	533	4.2	0.06	533	0.81	0.00
1997	2	772	83	0.25	772	4.7	0.05	772	0.80	0.00
1998	2	1,925	72	0.13	1,881	3.0	0.03	1,881	0.76	0.00
1999	2	784	81	0.28	784	4.8	0.07	784	0.89	0.00
2000	2	503	76	0.34	503	3.6	0.07	503	0.80	0.00
2001	2	389	75	0.45	387	3.4	0.09	387	0.77	0.01
2002	2	225	80	0.78	225	4.9	0.18	225	0.88	0.01
2003	2	279	76	0.48	279	3.5	0.09	279	0.76	0.01
2004	2	274	77	0.41	274	3.9	0.09	274	0.82	0.00
2005	2	397	76	0.33	397	3.5	0.06	397	0.79	0.00
2006	2	518	78	0.35	518	3.8	0.08	518	0.78	0.00
2007	2	272	90	0.36	272	6.6	0.09	272	0.91	0.00
2008	2	288	79	0.35	287	3.7	0.06	287	0.73	0.01
2009	2	413	80	0.31	411	4	0.05	411	0.76	0.00

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Table 6.–Page 2 of 2.

		Length (mm)			Weight (g)			Condition Factor		
Year	Age	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error	Sample Size	Mean	Standard Error
1996	3	3	100	5.55	3	8.4	1.68	3	0.81	0.06
1997	3	12	87	1.34	12	5.2	0.35	12	0.77	0.02
1998	3	20	84	3.39	19	5.5	0.99	19	0.81	0.02
1999	3	7	90	5.76	7	6.8	1.66	7	0.85	0.03
2000	3	14	86	2.36	14	5.3	0.63	14	0.79	0.01
2001	3	62	90	1.60	61	6.9	0.42	61	0.86	0.01
2002	3	6	110	7.24	6	13.8	2.67	6	1.00	0.03
2005	3	7	108	4.35	7	11.4	1.21	7	0.89	0.02
2006	3	32	99	1.89	32	8.9	0.55	32	0.89	0.02
2008	3	17	91	2.54	17	6.1	0.70	17	0.77	0.02
2001	4	1	125	-	1	18.8	-	1	0.96	-

Table 7.–Chignik River sockeye salmon escapement, estimated number of smolts by freshwater age, smolts per spawner, adult return by freshwater age, return per spawner, and marine survival, by brood year, from 1991 to 2009.

Brood		Smolt Produced				Total	Smolt /	Adult Returns					Return /	Marine
Year	Escapement	Age-0.	Age-1.	Age-2.	Age-3.	Smolt	Spawner	Age-0.	Age-1.	Age-2.	Age-3.	Total	Spawner	Survival
1991	1,040,098	NA	NA	4,270,636	0	4,270,636	4.11	6,868	1,795,467	737,680	11,621	2,551,636	2.45	NA
1992	764,436	NA	7,263,054	5,178,450	5,018	12,446,522	16.28	152,005	649,920	1,159,871	93,372	2,055,168	2.69	17%
1993	697,377	0	2,843,222	731,099	122,289	3,696,610	5.30	16,270	457,189	1,998,416	7,265	2,479,140	3.55	67%
1994	966,909	735,916	1,200,793	13,738,356	158,056	15,833,121	16.37	251	1,818,410	1,483,548	2,467	3,304,676	3.42	21%
1995	739,920	80,254	11,172,150	20,374,245	78,798	31,705,447	42.85	36,053	2,391,218	942,680	17,366	3,387,317	4.58	11%
1996	749,137	528,846	5,790,587	8,221,631	160,017	14,701,081	19.63	145,189	1,998,842	877,180	13,958	3,035,168	4.05	21%
1997	775,618	75,560	12,705,935	4,645,121	516,723	17,943,339	23.13	15,852	770,645	956,005	5,627	1,748,129	2.25	10%
1998	701,128	73,364	8,047,526	5,024,666	72,184	13,217,740	18.85	5,515	1,030,709	350,167	1,052	1,387,443	1.98	10%
1999	715,966	1,270,101	18,940,752	2,223,996	0	22,434,849	31.34	26,176	913,849	403,536	1,663	1,345,224	1.88	6%
2000	805,225	521,546	13,980,423	1,449,494	0	15,951,463	19.81	15,176	1,988,373	699,285	2,729	2,705,565	3.36	17%
2001	1,136,918	440,947	5,146,278	2,239,716	32,889	7,859,830	6.91	79,627	1,031,100	696,415	482	1,807,624	1.59	23%
2002	725,220	155,047	6,172,902	1,468,208	119,614	7,915,771	10.91	20,480	700,976	412,758	2,078	1,136,291	1.57	14%
2003	684,145	244,206	2,075,681	2,847,624	0	5,167,511	7.55							
2004	578,259	859,211	2,849,043	1,028,865	41,136	4,778,255	8.26							
2005	581,382	1,744,370	1,926,682	987,928	0	4,658,980	8.01							
2006	735,493	9,286	3,309,894	4,288,491										
2007	654,974	1,017,498	3,777,572											
2008	706,058	110,446												
2009	720,062													
1994-2002 Average														20%

Table 8.–Estimated marine survival of sockeye salmon smolts from the Chignik River by emigration year and ocean age adult returns for each emigration year from 1994 to 2009.

Emigration	Smolt estimates					Adult returns					Marine
Year	Age-0.	Age-1.	Age-2.	Age-3.	Total	Age-.1	Age-.2	Age-.3	Age-.4	Total	Survival
1994	0	7,263,054	4,270,636	0	11,533,690	4,063	208,548	1,207,343	9,782	1,429,736	12%
1995	735,916	2,843,222	5,178,450	0	8,757,588	14,186	343,315	1,267,456	3,975	1,628,932	19%
1996[a]	80,245	1,200,793	731,099	5,018	2,017,155	28,209	675,848	3,225,337	16,857	3,946,250	196%
1997	528,846	11,172,150	13,738,356	122,289	25,561,641	11,814	1,232,238	2,767,364	15,622	4,027,038	16%
1998	75,560	5,790,587	20,374,245	158,056	26,398,448	601	170,545	2,756,954	31,741	2,959,840	11%
1999	73,364	12,705,935	8,221,631	78,798	21,079,728	446	136,822	1,524,022	9,416	1,670,706	8%
2000	1,270,101	8,047,526	4,645,121	160,017	14,122,765	5,460	404,961	1,611,191	5,237	2,026,848	14%
2001	521,546	18,940,752	5,024,666	516,723	25,003,687	324	229,693	1,051,600	3,203	1,284,819	5%
2002	440,947	13,980,423	2,223,996	72,184	16,717,551	4,164	432,476	2,013,710	22,238	2,472,588	15%
2003	155,047	5,146,278	1,449,494	0	6,750,819	2,282	158,558	1,540,591	51,097	1,752,528	26%
2004	244,206	6,172,902	2,239,716	0	8,656,824	1,316	178,412	1,285,999	17,447	1,483,173	17%
2005	859,211	2,075,681	1,468,208	32,889	4,435,988	804	204,180	1,205,391	9,166	1,419,540	32%
2006	1,744,370	2,849,043	2,847,624	119,614	7,560,651	771	169,698	1,655,282			
2007	9,286	1,926,682	1,028,865	0	2,964,833	793	429,607				
2008	1,017,498	3,309,894	987,928	41,136	5,356,455	1,734					
2009	110,446	3,777,572	4,288,491	0	8,176,509						
1994-2005 Average (Excluding 1996)											16%

[a] 1996 data are presented, but considered erroneous due to unrealistic survival estimates and thus not used in subsequent calculations.

Table 9.–Water temperature for Black Lake in 2009 by depth and date.

Depth	Temperature (^oC)			
(m)	17-May	15-Jun	9-Jul	13-Aug
0.0	8.3	11.7	12.8	13.5
0.5	11.3	11.9	13.4	13.4
1.0	11.5	11.9	13.6	13.4
1.5	11.7	11.9	13.8	13.3
2.0	11.8	11.9	13.9	13.3
2.5	11.9	11.9	13.9	13.3
3.0	12.0	11.9		13.3
3.5	12.0	11.9		13.2
4.0				13.2

Table 10.–Dissolved oxygen for Black Lake in 2009 by depth and date.

Depth	Dissolved oxygen (mg/L)			
(m)	17-May	15-Jun	9-Jul	13-Aug
0.0	7.9	7.2	7.6	10.0
0.5	8.1	7.5	7.0	9.5
1.0	8.0	7.1	6.9	9.4
1.5	7.7	6.9	6.7	9.3
2.0	7.6	6.9	6.6	9.2
2.5	7.6	6.8	6.5	9.2
3.0	5.9	6.4		9.1
3.5		5.1		9.1
4.0				9.0

Table 11.–Chignik Lake water temperature (°C) and DO (mg/L) averaged over all stations by depth and date in 2009.

Depth	Temperature (°C)				Dissolved oxygen (mg/L)			
(m)	15-May	8-Jun	2-Jul	12-Aug	15-May	8-Jun	2-Jul	12-Aug
0.0	5.0	8.5	9.6	11.8	10.1	9.1	9.1	9.5
0.5	5.0	8.3	9.6	11.6	10.2	9.2	8.8	9.2
1.0	5.0	8.2	9.6	11.5	10.3	9.1	8.8	9.1
1.5	4.9	8.1	9.6	11.5	10.4	9.0	8.8	9.0
2.0	4.9	7.9	9.6	11.4	10.3	9.0	8.7	8.9
2.5	4.8	7.9	9.6	11.3	10.4	8.9	8.7	8.9
3.0	4.8	7.7	9.6	11.3	10.4	8.8	8.7	8.8
3.5	4.8	7.6	9.6	11.3	10.4	8.8	8.6	8.6
4.0	4.8	7.5	9.6	11.2	10.4	8.8	8.6	8.6
4.5	4.8	7.5	9.6	11.2	10.5	8.7	8.6	8.6
5.0	4.8	7.4	9.6	11.2	10.4	8.7	8.6	8.5
6.0	4.7	7.3	9.6	11.2	10.4	8.7	8.6	8.5
7.0	4.8	7.2	9.6	11.2	10.5	8.7	8.6	8.4
8.0	4.7	7.2	9.6	11.2	10.3	8.6	8.6	8.5
9.0	4.7	7.2	9.6	11.2	10.4	8.6	8.6	8.4
10.0	4.7	7.2	9.6	11.2	10.3	8.6	8.6	8.5
11.0	4.7	7.1	9.6	11.2	10.3	8.6	8.6	8.5
12.0	4.7	7.1	9.6	11.2	10.3	8.7	8.6	8.5
13.0	4.7	7.1	9.6	11.2	10.2	8.6	8.6	8.4
14.0	4.7	7.0	9.6	11.1	10.2	8.6	8.5	8.4
15.0	4.6	7.0	9.6	11.1	10.2	8.6	8.5	8.4
16.0	4.6	7.0	9.5	11.1	10.2	8.6	8.3	8.4
17.0	4.6	7.0	9.5	11.1	10.2	8.6	8.3	8.4
18.0	4.6	7.0	9.4	11.1	10.2	8.6	8.3	8.4
19.0	4.6	6.9	9.4	11.1	10.1	8.6	8.2	8.3
20.0	4.6	6.9	9.3	11.1	10.2	8.6	8.2	8.3
21.0	4.6	6.9	9.3	11.1	10.1	8.5	8.2	8.6
22.0	4.6	6.9	9.2	11.1	10.1	8.4	8.2	8.6
23.0	4.5	6.9	9.2	11.1	10.2	8.4	8.2	8.6
24.0	4.5	6.9	9.2	11.1	10.1	8.2	8.2	8.6
25.0	4.5	6.8	9.2	11.1	10.1	8.2	8.1	8.6
30.0	4.5	6.8	9.1	11.0	10.2	8.2	8.1	8.7

Table 12.–Euphotic Zone Depth (EZD) and Euphotic Volume (EV) of Black and Chignik lakes, by month, 2009.

		2009				
Lake		May	June	July	August	Average[a]
Black[b]	EZD	4.4	6.7	4.1	4.0	4.8
	Mean EV[c]	78.1	78.1	78.1	78.1	78.1
Chignik	EZD	4.5	7.3	15.2	7.5	8.6
	Mean EV[c]	108.5	176.5	365.4	179.7	207.5

[a] Averages calculated from mean light reading (kLux) data.

[b] The mean depth of Black Lake is 1.9 m; this value was used for the EV calculations instead of the EZD's, when the EZD exceeded 1.9 m.

[c] EV units = x 10^6 m^3

Table 13.–Average monthly solar illuminance readings by depth and month for Chignik Lake, 2009.

	Solar illuminance (kLux)				
Depth	May	June	July	August	Average
0.0	1,518.8	2,211.0	185.0	556.0	1,304.9
0.5	1,050.8	1,638.0	216.6	282.0	968.5
1.0	623.3	1,214.3	113.2	230.8	650.2
1.5	416.0	705.5	87.2	167.3	402.9
2.0	280.0	448.5	73.2	122.3	267.2
2.5	177.3	330.8	59.5	87.0	189.2
3.0	126.5	243.3	50.6	65.0	140.1
3.5	88.3	185.0	44.4	50.0	105.9
4.0	55.3	146.2	38.5	37.3	80.0
4.5	38.7	110.0	33.1	26.5	60.6
5.0	31.4	106.0	27.3	18.8	54.9
6.0	15.8	64.8	19.5	10.4	33.4
7.0	10.1	29.8	18.8	9.1	19.6
8.0	10.3	16.0	17.2	6.1	14.4
9.0	-	11.0	17.4	-	14.3
10.0	-	-	11.4	-	11.4
11.0	-	-	7.7	-	7.7
12.0	-	-	-	-	-

Table 14.–Water quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Black Lake, 2009.

	2009				
	17-May	15-Jun	9-Jul	13-Aug	Average[a]
pH	7.8	7.8	7.4	7.6	7.7
Alkalinity (mg/L)	23.5	22.5	23.5	24.5	23.5
Total P (µg/L P)	42.5	30.1	24.2	67.5	41.1
TKN (µg/L N)	416.0	129.0	130.0	259.0	233.5
Ammonia (µg/L N)	1.6	3.2	3.8	1.6	2.6
Nitrate + Nitrite (µg/L N)	4.5	0.0	0.0	0.5	1.3
Chlorophyll *a* (µg/L)	1.0	1.3	2.6	7.1	3.0
Phaeophytin *a* (µg/L)	0.4	0.8	0.6	3.7	1.4

[a] Averaged values do not always exactly match the values reported in Appendix F due to rounding.

Table 15.–Water-quality parameters, nutrient concentrations, and photosynthetic pigments by sample date for Chignik Lake, 2009. All stations and depths are averaged for each sample date.

	2009				
	15-May	8-Jun	2-Jul	12-Aug	Average[a]
pH	7.4	7.7	7.3	7.7	7.5
Alkalinity (mg/L)	24.0	22.9	21.9	22.9	22.9
Total P (µg/L P)	14.5	15.3	22.6	23.6	22.3
TKN (µg/L N)[b]	35.0	42.0	80.0	162.0	79.8
Ammonia (µg/L N)[b]	3.4	3.4	11.7	4.7	5.8
Nitrate + Nitrite (µg/L N)	193.0	159.9	140.3	114.6	151.8
Chlorophyll *a* (µg/L)	4.4	0.8	1.5	2.8	2.3
Phaeophytin *a* (µg/L)	0.8	0.5	0.4	0.6	0.6

[a] Averaged values do not always exactly match the values reported in Appendix F due to rounding.

[b] Station 2 only.

Table 16.–Average number of zooplankton by taxon per m^2 from Black Lake by sample date, 2009.

Taxon	Sample date				Seasonal
	17-May	15-Jun	9-Jul	13-Aug	average
Copepods					
Epischura	11,412	1,115	1,327	1,062	3,729
Diaptomus	796	669	3,185	5,308	2,490
Cyclops	16,985	28,981	18,312	31,847	24,031
Nauplii	36,624	44,363	6,104	28,662	28,938
					0
Total copepods	65,817	75,128	28,928	66,879	59,188
Cladocerans					
Bosmina	2,123	11,592	23,355	159,766	49,209
Ovig. *Bosmina*	2,919	5,573	6,635	33,439	12,142
Daphnia l.	265	0	0	0	66
Total cladocerans	5,307	17,165	29,990	193,205	61,417
Total copepods + cladocerans	71,124	92,293	58,918	260,084	120,605

Table 17.–Biomass estimates (mg dry weight/m^2) of the major Black Lake zooplankton taxa by sample date, 2009.

Taxon	Sample date 17-May	15-Jun	9-Jul	13-Aug	Seasonal average	Weighted average
Copepods						
Epischura	10.9	0.9	0.7	0.5	3.3	3.2
Diaptomus	3.2	2.6	4.4	12.5	5.7	5.4
Cyclops	15.3	23.3	23.3	34.9	24.2	24.0
Harpaticus	-	-	-	-	-	-
Total copepods	29.4	26.8	28.4	47.9	33.1	32.6
Cladocerans						
Bosmina	3.9	11.5	23.7	159.1	49.6	49.5
Ovigerous *Bosmina*	8.6	9.8	8.3	52.8	19.9	19.8
Daphnia longiremis	-	-	-	-	-	-
Total cladocerans	12.5	21.3	32.0	211.9	69.4	69.3
Total Biomass	41.9	48.1	60.4	259.8	102.6	101.9

Table 18.–Average length (mm) of zooplankton in Black Lake by sample date, 2009.

Taxon	Sample date 17-May	15-Jun	9-Jul	13-Aug	Seasonal average
Copepods					
Epischura	0.58	0.54	0.46	0.45	0.51
Diaptomus	0.98	0.96	0.67	0.81	0.86
Cyclops	0.52	0.50	0.61	0.57	0.55
Harpaticus	-	-	-	-	-
Cladocerans					
Bosmina	0.44	0.33	0.33	0.33	0.36
Ovigerous *Bosmina*	0.56	0.44	0.37	0.41	0.45
Daphnia longiremis	-	-	-	-	-

Table 19.–Average number of zooplankton by taxon per m^2 from Chignik Lake, by sample date, 2009.

Taxon	Sample date 15-May	8-Jun	2-Jul	12-Aug	Seasonal average
Copepods					
Epischura	1,228	929	3,490	14,909	5,139
Ovigerous *Epischura*	-	-	-	-	-
Diaptomus [a]	-	12,158	11,611	114,345	46,038
Ovigerous *Diaptomus*	-	553	212	6,144	2,303
Cyclops	235,291	76,732	158,599	50,733	130,339
Ovigerous *Cyclops*	-	-	7,909	11,983	9,946
Harpaticus	-	863	159	995	672
Nauplii	17,353	4,959	18,564	151,387	48,066
Total copepods	253,872	96,194	200,544	350,496	225,277
Cladocerans					
Bosmina	1,068	1,974	4,857	79,857	21,939
Ovigerous *Bosmina*	-	332	1,539	4,097	1,989
Daphnia longiremis	9,743	7,265	14,238	143,326	43,643
Ovigerous *Daphnia longiremis*	996	1,261	15,924	37,235	13,854
Total cladocerans	11,807	10,832	36,558	264,515	80,928
Total Copepods + Cladocerans	265,679	107,026	237,102	615,011	306,205

[a] No biomass estimate available

Table 20.–Biomass estimates (mg dry weight/m^2) of the major zooplankton species in Chignik Lake by sample date, 2009.

Taxon	Sample date 5/15	6/8	7/2	8/12	Seasonal average	Weighted average
Copepods						
Epischura	3.2	1.6	3.1	10.5	4.6	3.5
Ovigerous *Epischura*	-	-	-	-	-	-
Diaptomus	-	42.4	33.5	247.9	80.9	56.5
Ovigerous *Diaptomus*	-	7.8	3.8	59.2	17.7	10.0
Cyclops	273.6	136.4	573.4	67.9	262.8	191.6
Ovigerous *Cyclops*	-	-	55.2	81.6	34.2	28.3
Harpaticus	-	0.6	0.6	0.9	0.5	0.2
Total Copepods	276.8	188.9	669.6	467.8	400.8	290.1
Cladocerans						
Bosmina	1.7	2.0	6.0	83.0	23.2	15.5
Ovigerous *Bosmina*	-	1.0	2.6	6.5	2.5	1.9
Daphnia longiremis	12.8	8.8	14.1	183.4	54.8	34.3
Ovigerous *Daphnia longiremis*	5.6	3.8	54.7	88.0	38.0	28.8
Total Cladocerans	20.1	15.7	77.3	360.9	118.5	80.5
Total Biomass	296.9	204.6	746.9	828.7	519.3	370.6

Table 21.–Average length (mm) of zooplankton from Chignik Lake by sample date, 2009.

Taxon	Sample date 5/15	6/8	7/2	8/12	Seasonal average
Copepods					
Epischura	0.74	0.65	0.56	0.52	0.60
Ovigerous *Epischura*	-	-	-	-	-
Diaptomus	1.05	0.91	0.91	0.76	0.88
Ovigerous *Diaptomus*	-	1.34	1.42	1.33	1.36
Cyclops	0.59	0.70	0.91	0.61	0.70
Ovigerous *Cyclops*	1.21	-	1.35	1.35	1.33
Harpaticus	-	-	-	0.44	0.48
Cladocerans					
Bosmina	0.42	0.36	0.37	0.34	0.37
Ovigerous *Bosmina*	-	0.47	0.42	0.42	0.44
Daphnia longiremis	0.56	0.54	0.49	0.54	0.53
Ovigerous *Daphnia longiremis*	0.96	0.83	0.82	0.72	0.79

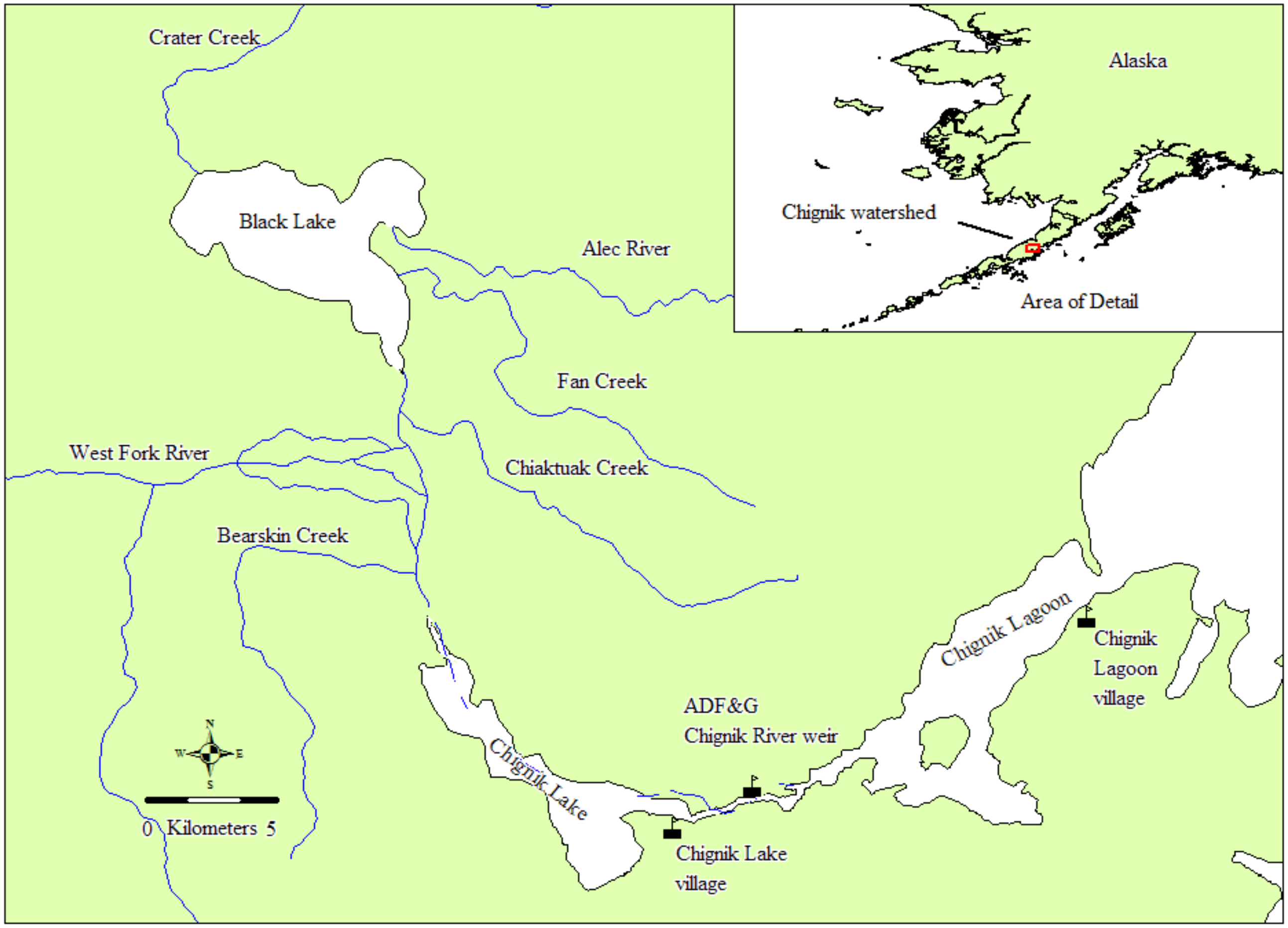


Figure 1.–Map of the Chignik River watershed.

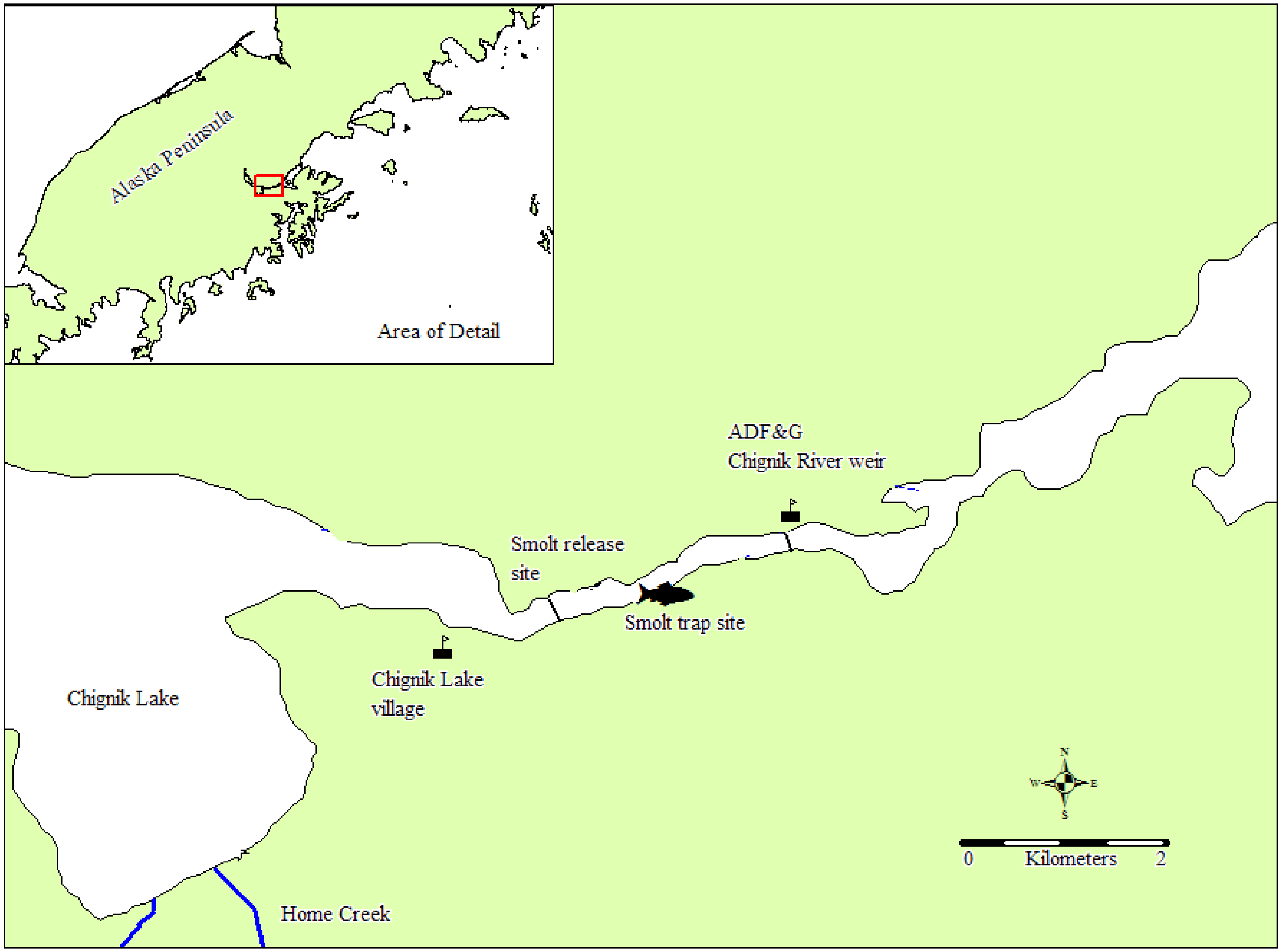


Figure 2.–Location of the traps and the release site of marked smolts in the Chignik River, Alaska, 2009.

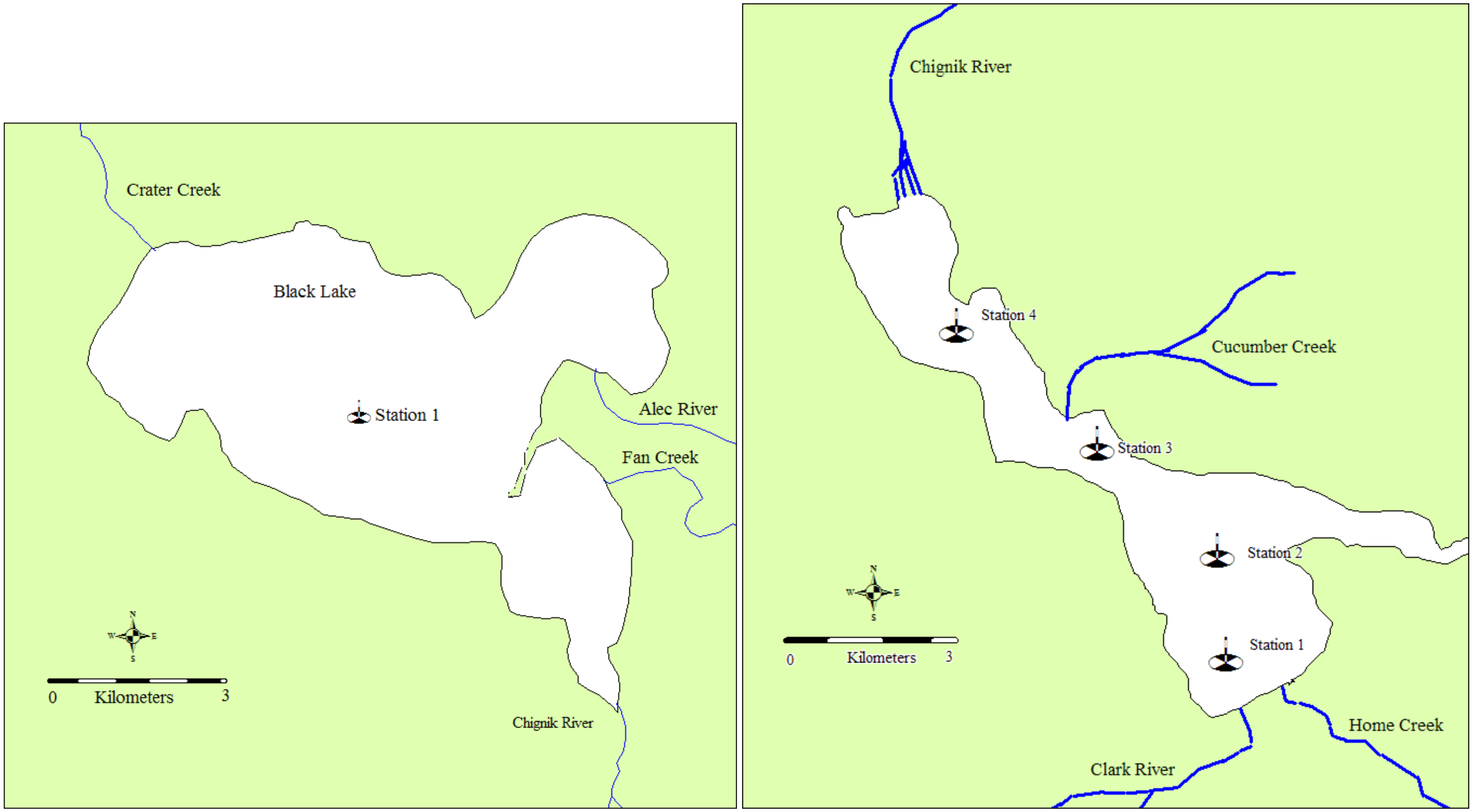


Figure 3.–Location of the Black Lake and Chignik Lake limnology sampling stations, 2009.

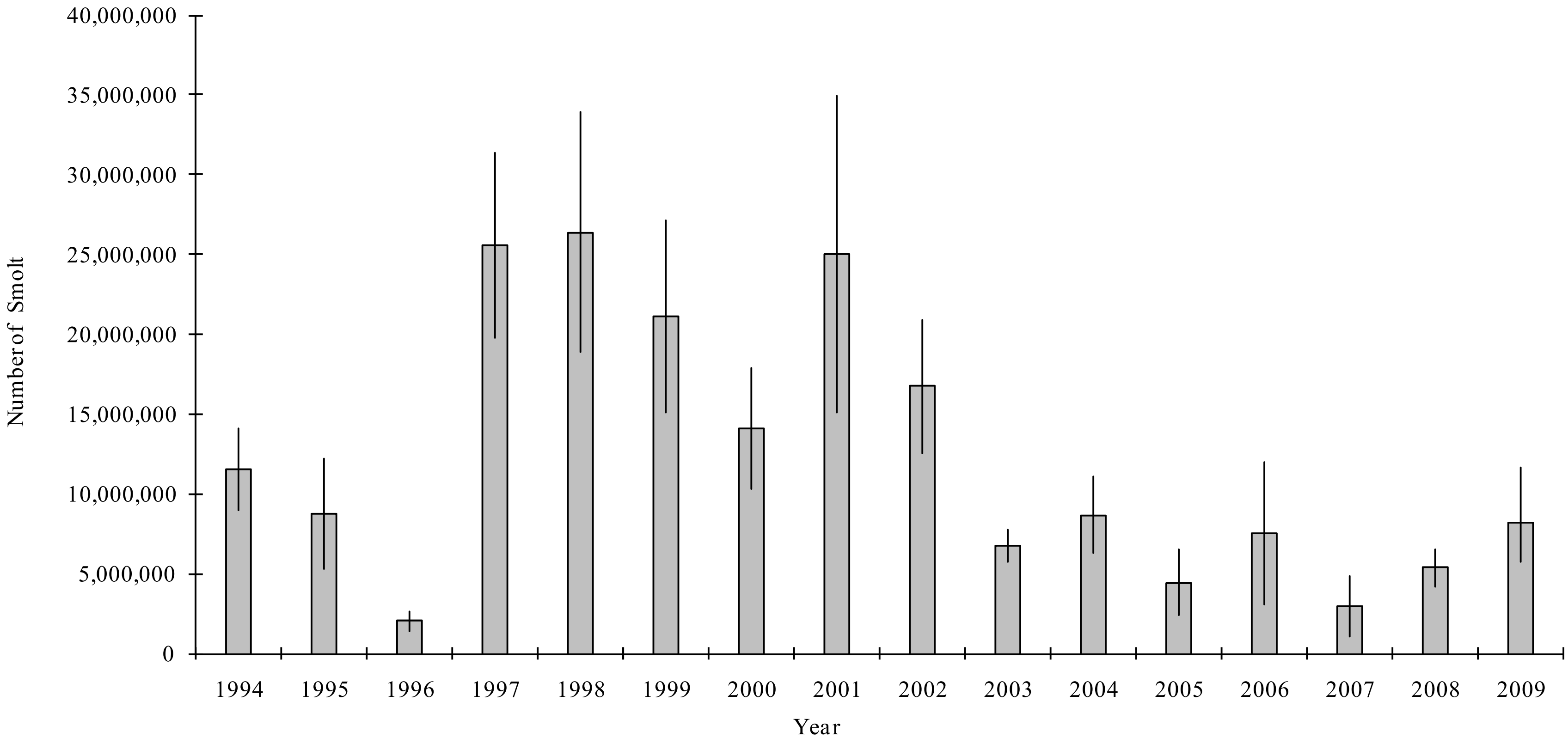


Figure 4.–Annual sockeye salmon smolt emigration estimates and corresponding 95% confidence intervals, Chignik River, 1994–2009. Emigration estimates from 1996 were underestimated.

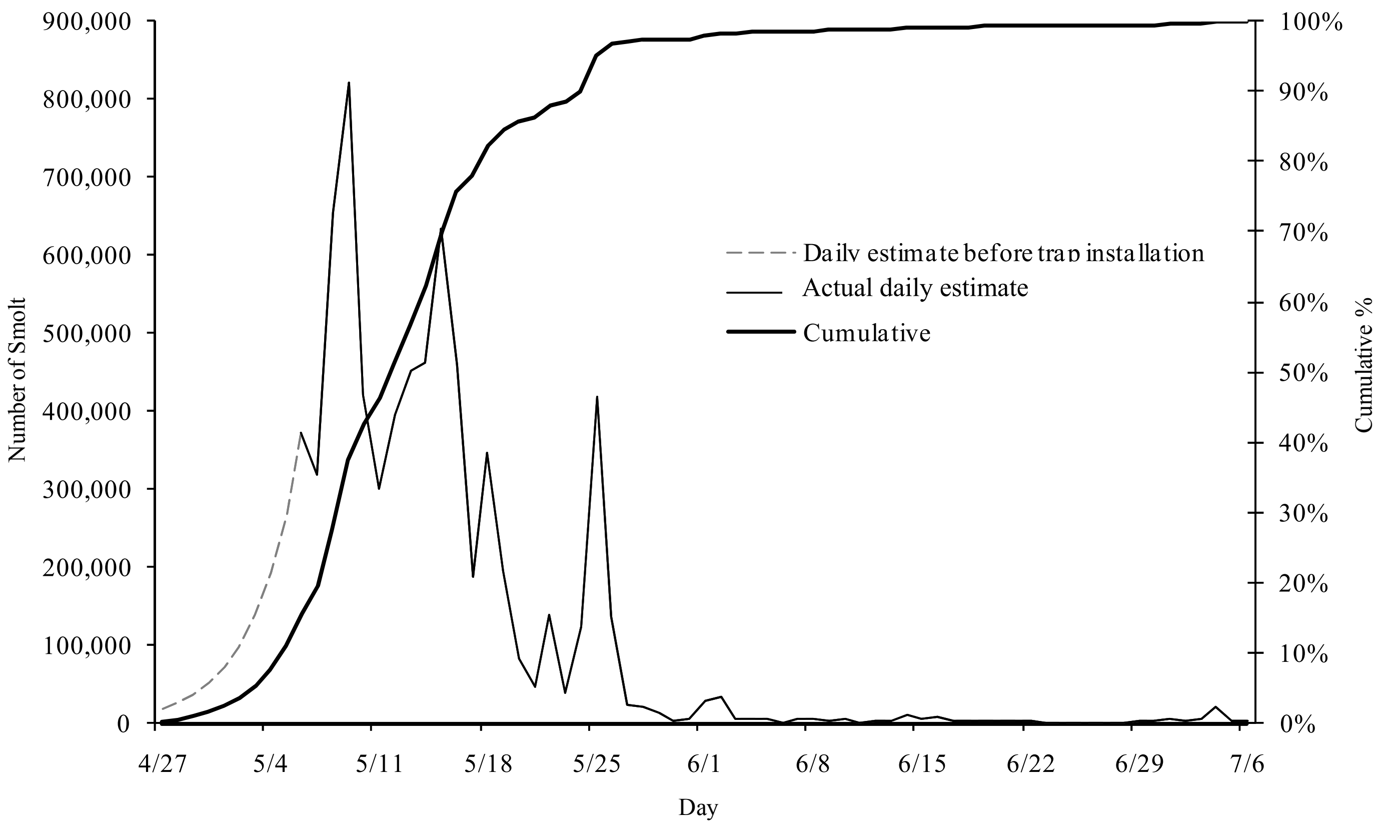


Figure 5.–Estimated and actual daily and corresponding cumulative percentage of the sockeye salmon smolt emigration from the Chignik River in 2009.

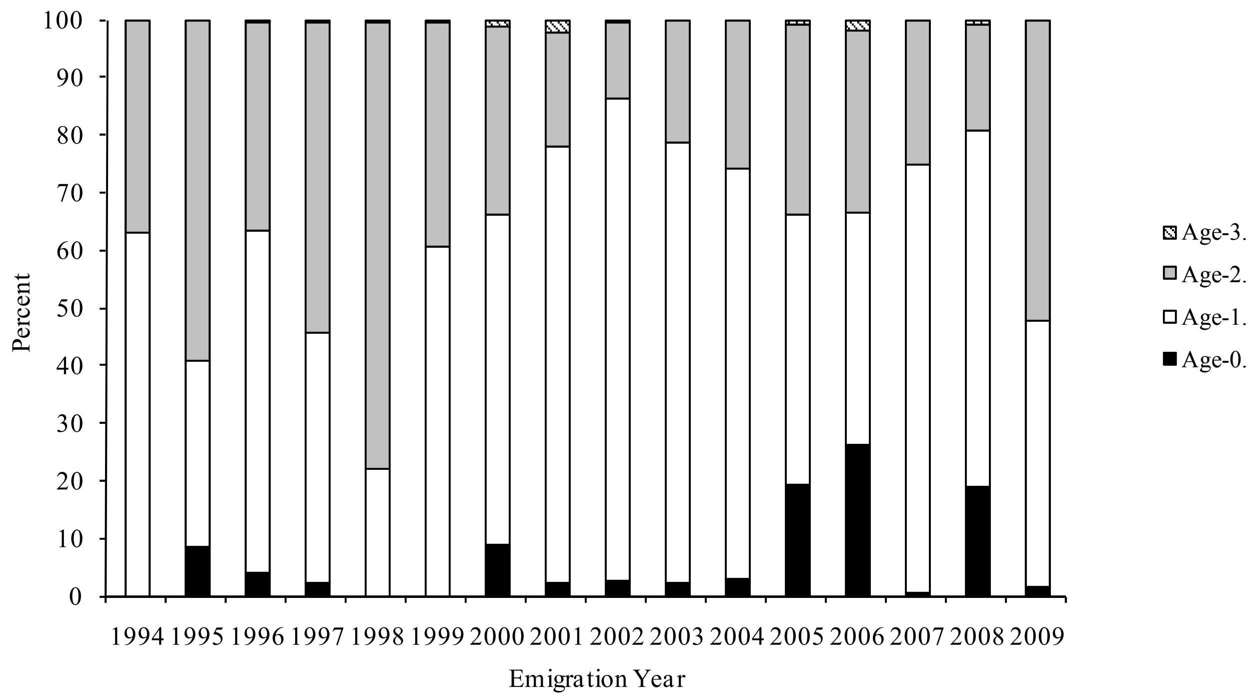


Figure 6.–A comparison of the estimated age structure of age-0. to age-3. sockeye salmon smolt emigrations from the Chignik River, 1994–2009.

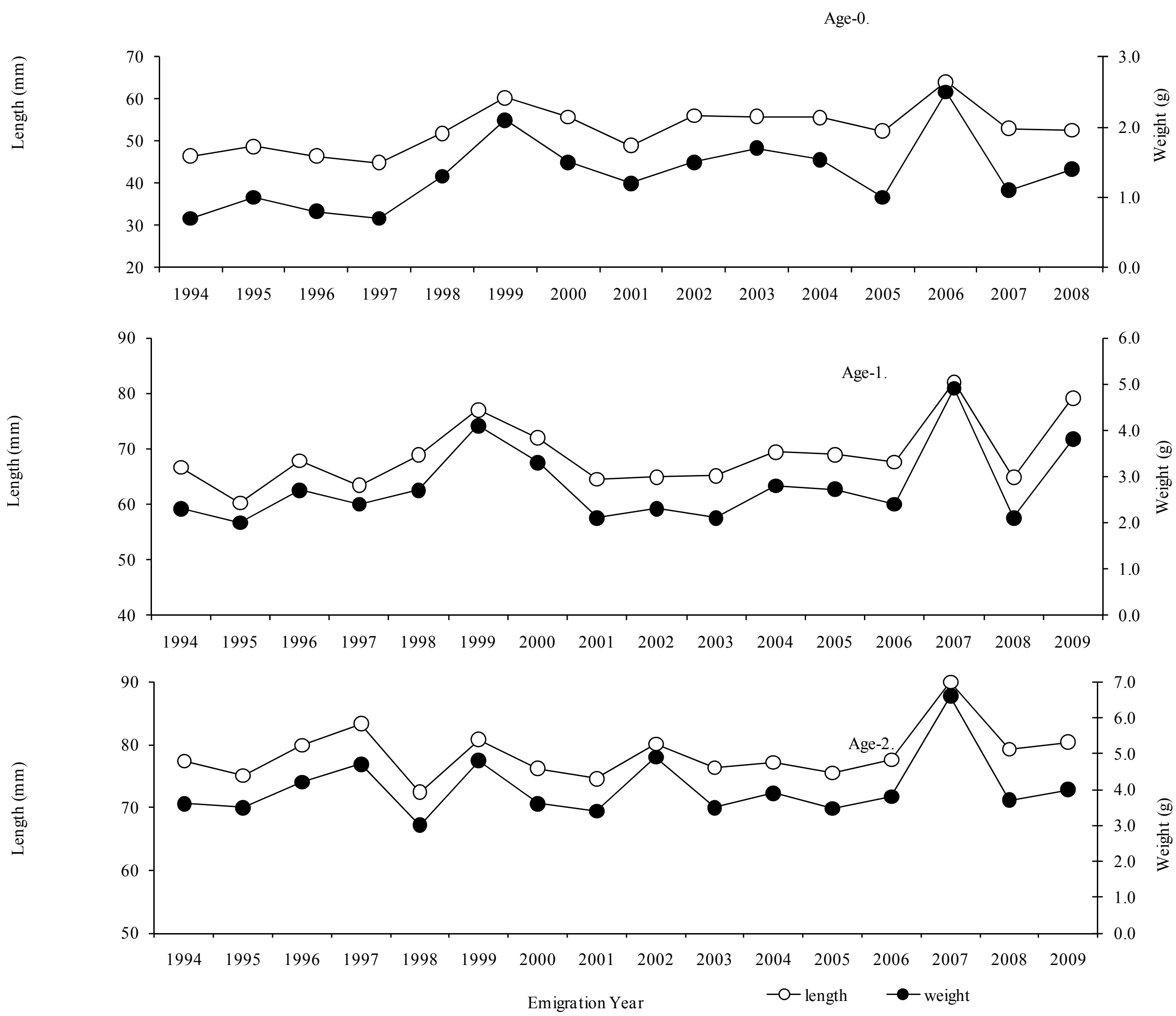


Figure 7.–Average length and weight of age-1. and age-2. sockeye salmon, by year from 1994 to 2009.

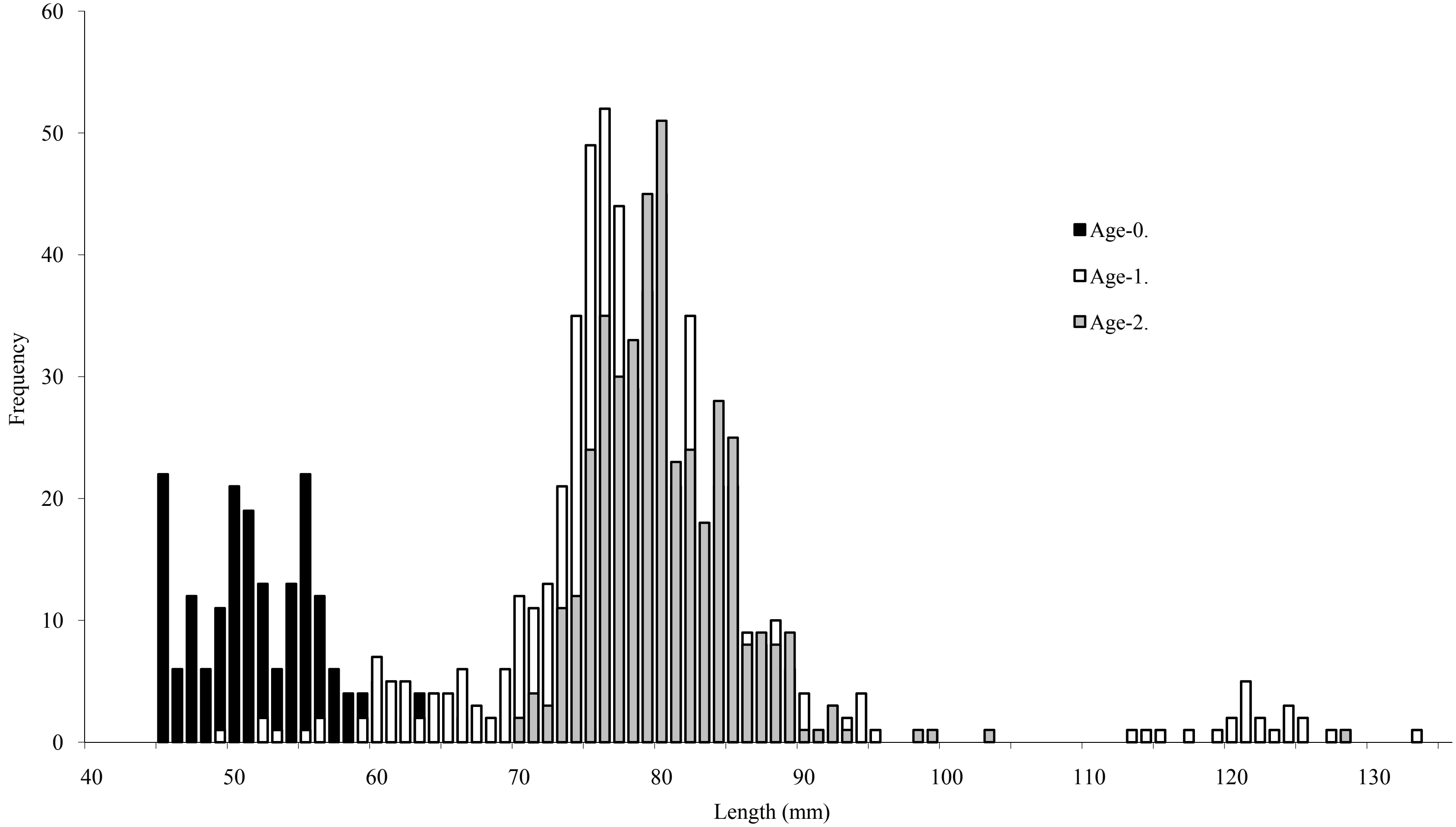


Figure 8.–Length frequency histogram of sockeye salmon smolts from the Chignik River in 2009 by age.

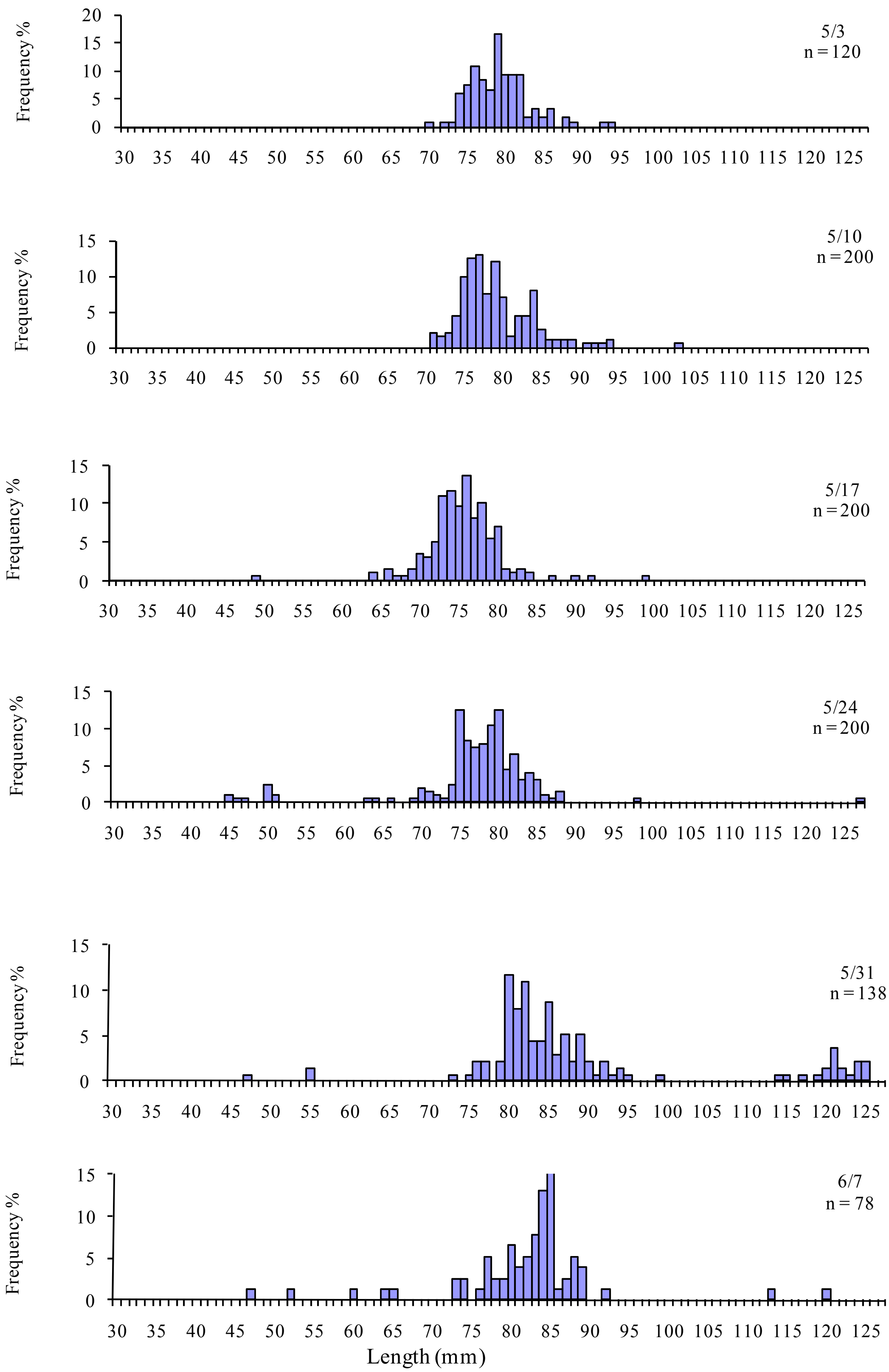
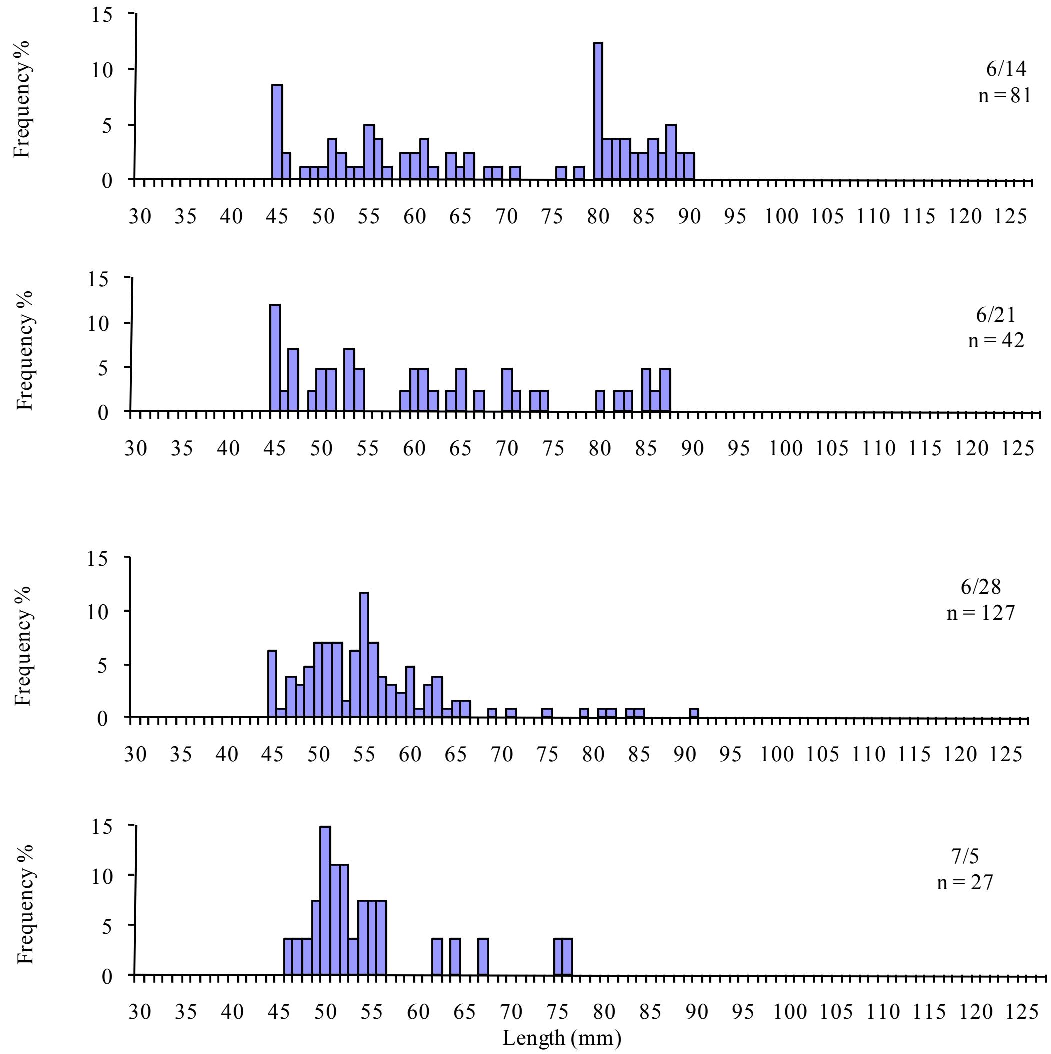


Figure 9.–Length frequency histograms of weekly total sockeye salmon catch samples in the screw traps in 2009.

Figure 9.–page 2 of 2.



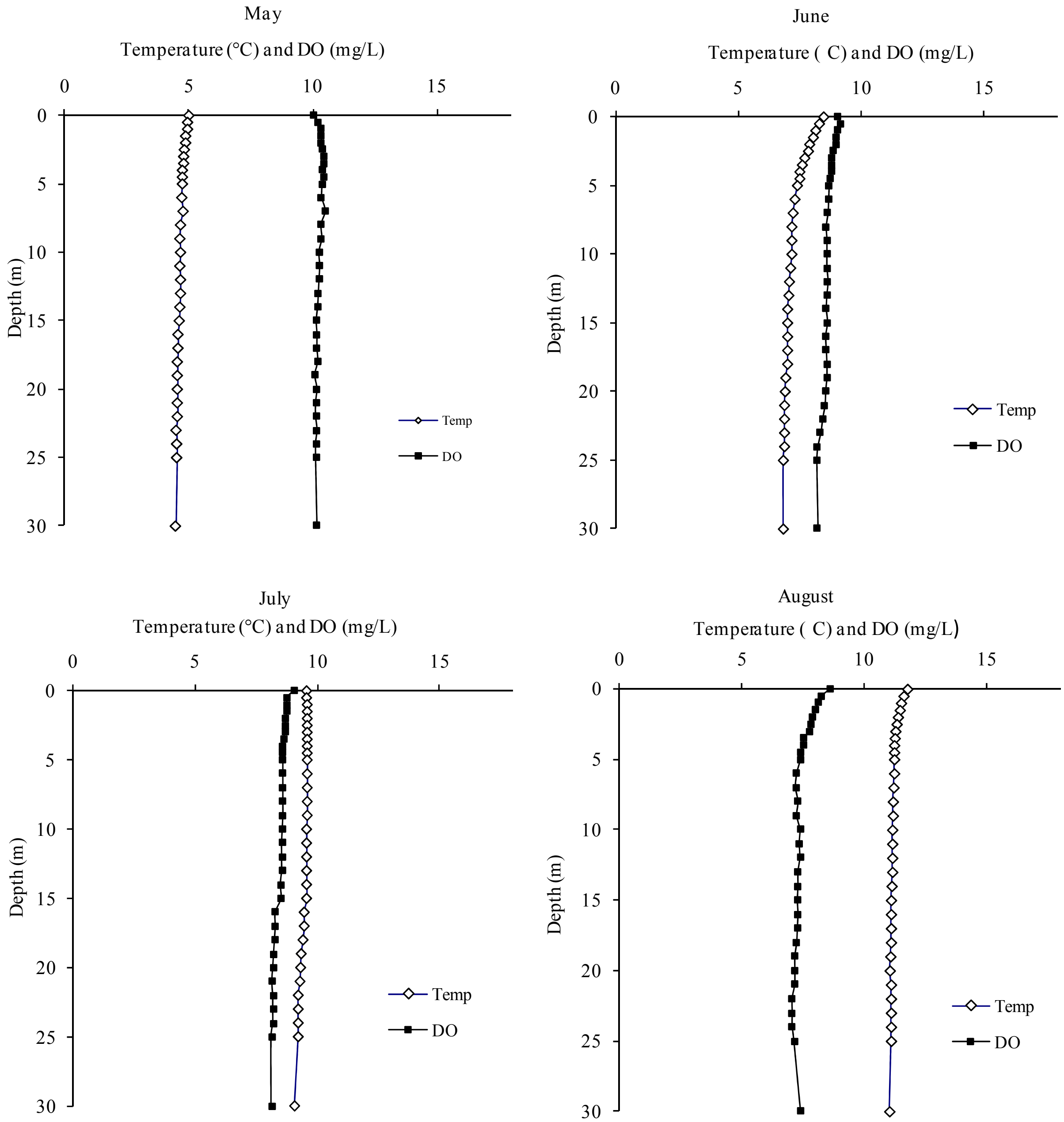


Figure 10.–Mean monthly temperature (°C) and dissolved oxygen (DO) profiles in Black Lake in 2009.

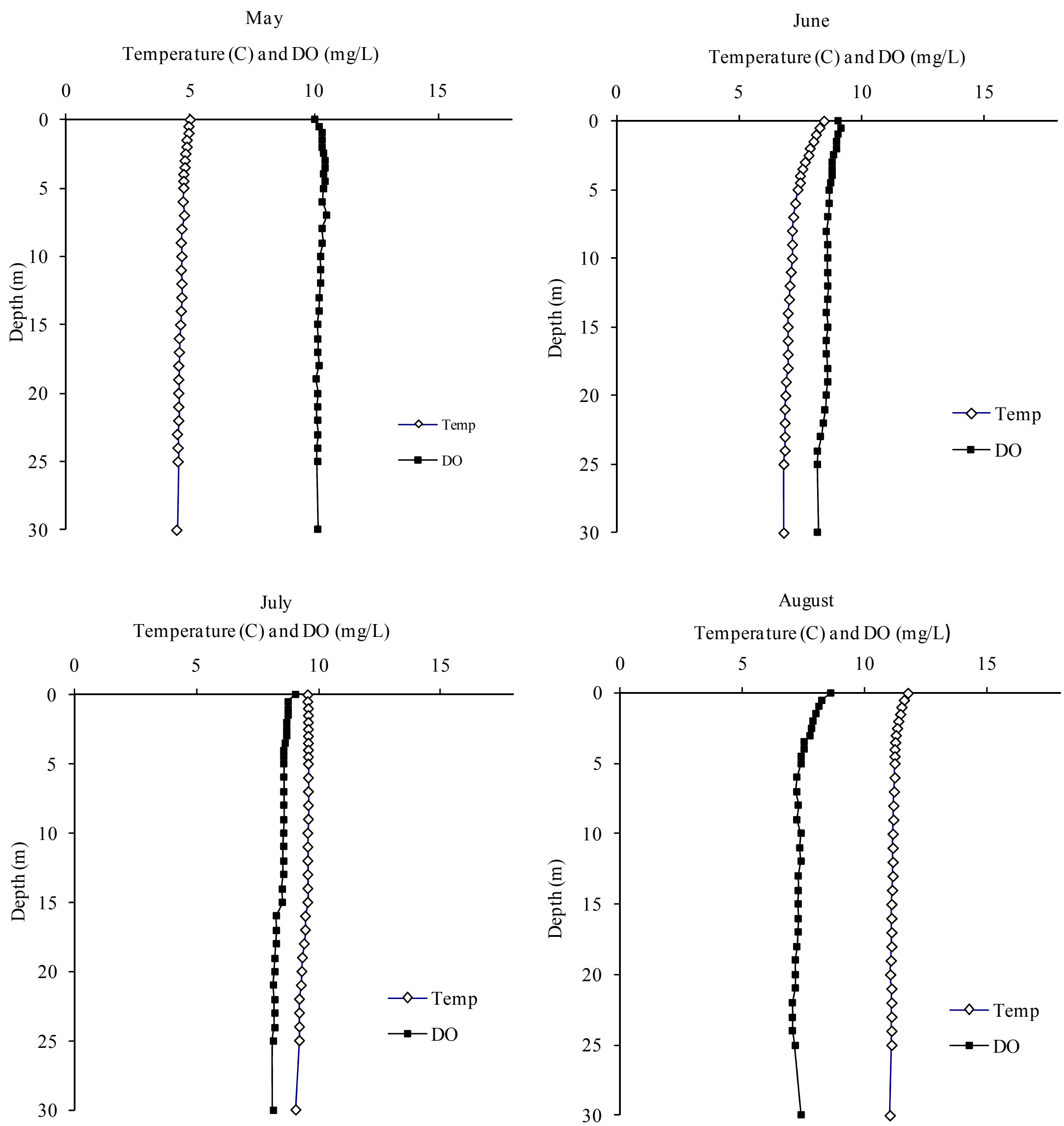
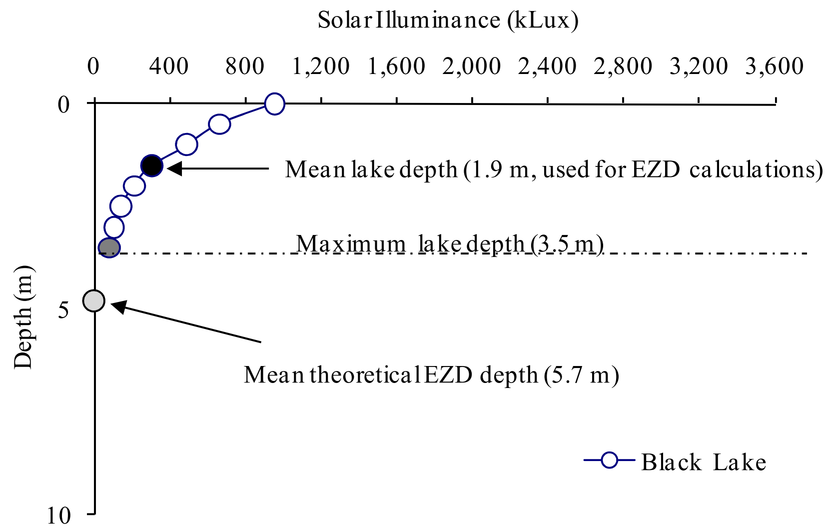


Figure 11.–Mean monthly temperature and dissolved oxygen profiles in Chignik Lake in 2009.



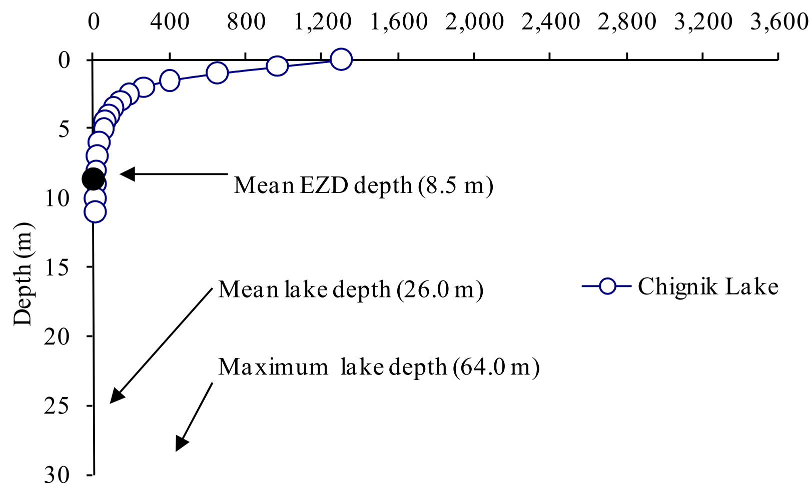


Figure 12.–Light penetration curves relative to mean depth, EZD, and maximum depth in Chignik and Black lakes in 2009.

APPENDIX A. ADF&G PROTOCOL FOR GENETIC SAMPLING

Appendix A1.–ADF&G protocol for genetic sampling.

Collection of Axillary Process (AX) Tissue Samples for DNA

ADF&G Gene Conservation Lab, Anchorage

I. General Information

We use axillary processes from individual fish to determine the genetic characteristics and profile of a particular run or stock of fish or to determine the stock composition of fisheries. This is a non-lethal method of collecting genetic data from adult fish. The most important thing to remember in collecting samples is that **only quality samples give quality results**. If sampling from carcasses, fish need to be as freshly dead as possible. DO NOT sample tissue from fungal covered carcasses.

II. Sample procedure:

1. Set-up: Select sampling container that will provide at least 1ml per sampled AX (i.e. if you plan to sample 200 fish use at least a 250ml container). Fill sampling container with alcohol. Fill out adhesive label on container with information requested. Get out paper towels and dognail clipper.

2. Sample from the same side of every fish to avoid double-sampling individuals (only sample one piece of tissue from each fish).

3. Wipe the axillary process with a paper towel. Using dog toenail clipper, remove the entire AX and place the tissue into the sampling container.

4. Repeat process until the container has no more than 1 tissue per ml (ie. if you are sampling into 250ml bottle, stop at 200 samples). Replace lid on container. Invert container several times to distribute alcohol.

5. After 24 hours, "refresh" step - pour out the alcohol from the sampling container and pour in fresh alcohol to assure proper preservation.

6. Store 250ml bulk bottles containing tissues at room temperature, but away from heat and direct sun.

III. Supplies included with sampling kit:

1. Dog toenail clipper - use to cut off the axillary process
2. 250ml (max: 200 samples) bulk bottles: Nalgene containers
3. Ethanol (ETOH) – bulk in 500 ml Nalgene bottles or 20-liter qubetainers.
4. Paper towels – use to blot excess water or fish slime off fin
5. Printout of sampling instructions
6. Return shipment materials: HAZMAT paperwork, 4-G box, absorbent material, laminated "return address" labels, return shipment instructions.

VI. Shipping: HAZMAT paperwork is required for return shipment of these samples – see shipping instructions.

APPENDIX B. SMOLT TRAP CATCHES BY DAY

Appendix B1.–Actual daily counts and trap efficiency data of the Chignik River sockeye salmon smolt project, 2009.

	Actual Sockeye Smolt		Trap Efficiency Test				Incidental Catch[a]										
Date	Daily	Cum.	Marked	Daily Recoveries	Cum. Recoveries	Efficiency[b]	Soc Fry	Coho	Pink	Chnk	DV	SB	SC	SF	PS	PW	ISO
5/6	1,966	1,966	0	0	0	0.00%	319	15	0	2	7	239	3	0	93	0	1
5/7	1,677	3,643	0	0	0	0.00%	263	9	0	0	14	164	0	0	51	0	0
5/8	3,458	7,101	0	0	0	0.00%	591	11	0	0	1	387	1	1	38	0	1
5/9	4,332	11,433	3217	11	11	0.37%	585	24	0	1	5	228	2	1	37	0	0
5/10	2,220	13,653	0	5	16	0.53%	706	33	0	0	9	403	1	1	10	0	0
5/11	1,592	15,245	0	0	16	0.53%	492	5	0	0	15	445	1	0	16	0	0
5/12	2,084	17,329	0	0	16	0.53%	380	8	0	0	15	601	4	0	6	0	0
5/13	2,386	19,715	0	0	16	0.53%	230	13	0	0	12	294	2	0	6	0	0
5/14	2,436	22,151	0	0	16	0.53%	233	14	0	0	1	364	1	0	13	0	0
5/15	3,348	25,499	0	0	16	0.53%	280	10	0	0	9	719	0	0	11	0	0
5/16	1,716	27,215	2940	5	5	0.20%	375	7	0	0	7	419	1	0	1	0	0
5/17	702	27,917	0	4	9	0.34%	316	7	0	0	8	354	1	0	0	0	0
5/18	1,301	29,218	0	1	10	0.37%	187	14	0	0	3	448	0	0	1	0	2
5/19	735	29,953	0	0	10	0.37%	130	6	0	0	12	602	1	0	4	0	0
5/20	311	30,264	0	0	10	0.37%	140	8	0	0	8	435	0	0	2	0	0
5/21	124	30,388	762	1	1	0.26%	124	4	0	0	15	585	0	0	1	0	0
5/22	365	30,753	0	0	1	0.26%	56	7	0	0	9	454	1	0	5	0	0
5/23	104	30,857	0	0	1	0.26%	167	8	0	2	8	465	0	1	2	0	0
5/24	326	31,183	0	0	1	0.26%	73	10	0	0	18	330	0	0	0	0	0
5/25	1,100	32,283	0	0	1	0.26%	1,022	9	0	0	8	381	0	0	1	0	1
5/26	541	32,824	1264	2	2	0.24%	170	19	0	1	4	398	0	0	0	0	0
5/27	88	32,912	0	2	4	0.40%	44	9	0	1	4	528	0	1	0	0	1
5/28	81	32,993	0	0	4	0.40%	52	2	0	2	7	576	0	0	1	0	0
5/29	52	33,045	0	0	4	0.40%	37	2	0	1	5	328	1	0	1	0	0
5/30	11	33,056	0	0	4	0.40%	31	1	0	0	1	250	1	0	2	0	0
5/31	17	33,073	0	0	4	0.40%	34	5	0	4	4	516	2	0	1	0	1

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Appendix B1.–Page 2 of 3.

	Actual Sockeye Smolt		Trap Efficiency Test				Incidental Catch[a]										
Date	Daily	Cum.	Marked	Daily Recoveries	Cum. Recoveries	Efficiency[b]	Soc Fry	Coho	Pink	Chnk	DV	SB	SC	SF	PS	PW	ISO
6/1	109	33,182	0	0	4	0.40%	49	1	1	0	2	513	1	1	1	0	0
6/2	136	33,318	0	0	4	0.40%	54	3	0	0	2	256	0	1	2	0	0
6/3	19	33,337	0	0	4	0.40%	124	5	0	1	2	558	0	0	0	0	0
6/4	21	33,358	0	0	4	0.40%	17	38	0	0	2	320	0	0	2	0	0
6/5	21	33,379	0	0	4	0.40%	48	26	0	1	0	341	0	0	2	0	0
6/6	5	33,384	0	0	4	0.40%	9	6	0	0	1	258	1	1	0	1	0
6/7	25	33,409	0	0	4	0.40%	19	12	0	2	2	213	1	1	1	0	0
6/8	27	33,436	0	0	4	0.40%	11	0	0	7	0	238	0	0	2	0	0
6/9	14	33,450	0	0	4	0.40%	9	3	1	4	1	344	0	0	2	1	0
6/10	22	33,472	0	0	4	0.40%	12	3	0	6	0	461	0	0	0	0	0
6/11	6	33,478	0	0	4	0.40%	5	2	0	5	0	591	0	0	1	0	0
6/12	12	33,490	0	0	4	0.40%	3	1	3	4	0	404	1	0	0	0	0
6/13	16	33,506	0	0	4	0.40%	8	2	22	4	1	442	0	0	1	0	0
6/14	38	33,544	0	0	4	0.40%	17	1	9	4	0	449	2	1	1	0	0
6/15	27	33,571	0	0	4	0.40%	18	4	0	7	0	380	0	0	0	0	0
6/16	37	33,608	0	0	4	0.40%	6	4	0	11	1	125	0	2	1	3	1
6/17	9	33,617	0	0	4	0.40%	0	1	0	7	1	158	0	0	0	0	0
6/18	8	33,625	0	0	4	0.40%	6	2	0	1	0	94	1	0	1	0	0
6/19	15	33,640	0	0	4	0.40%	7	0	1	5	0	135	1	0	0	0	0
6/20	7	33,647	0	0	4	0.40%	26	0	1	8	0	189	1	0	1	0	0
6/21	7	33,654	0	0	4	0.40%	13	3	0	8	1	141	0	0	2	0	1
6/22	9	33,663	0	0	4	0.40%	19	1	0	6	0	181	0	0	0	0	0
6/23	6	33,669	0	0	4	0.40%	35	2	0	5	0	111	0	0	0	0	0
6/24	4	33,673	0	0	4	0.40%	16	2	0	2	1	118	0	0	0	0	0
6/25	4	33,677	0	0	4	0.40%	15	2	3	5	0	209	0	0	0	0	0
6/26	6	33,683	0	0	4	0.40%	31	1	7	3	1	218	0	0	0	2	1
6/27	6	33,689	0	0	4	0.40%	14	0	3	6	1	126	0	0	1	0	0
6/28	4	33,693	0	0	4	0.40%	28	2	0	0	0	179	0	0	0	0	0
6/29	8	33,701	0	0	4	0.40%	66	0	0	0	1	95	1	0	1	0	1
6/30	15	33,716	0	0	4	0.40%	20	0	0	1	0	52	0	0	0	1	0

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Appendix B1.–Page 3 of 3.

	Actual Sockeye Smolt		Trap Efficiency Test				Incidental Catch[a]										
Date	Daily	Cum.	Marked	Daily Recoveries	Cum. Recoveries	Efficiency[b]	Soc Fry	Coho	Pink	Chnk	DV	SB	SC	SF	PS	PW	ISO
7/1	24	33,740	0	0	4	0.40%	9	2	0	2	2	57	0	0	2	0	0
7/2	12	33,752	0	0	4	0.40%	3	0	0	6	2	33	2	0	0	0	1
7/3	24	33,776	0	0	4	0.40%	1	0	0	3	0	45	2	0	0	0	0
7/4	86	33,862	0	0	4	0.40%	3	0	0	1	0	56	1	0	0	0	0
7/5	12	33,874	0	0	4	0.40%	4	1	0	6	1	75	1	0	0	0	0
7/6	15	33,889	0	0	4	0.40%	4	1	0	0	2	54	0	0	0	0	1
Total		38,639	8,183	31	31	0.38%	7,766	391	51	145	236	19,132	39	12	327	8	13

[a] Soc Fry = sockeye salmon fry, Coho = juvenile coho salmon, Pink = juvenile pink salmon, Chnk = juvenile chinook salmon, DV = Dolly Varden, SB = stickleback, SC = sculpin, SF = starry flounder, PS = pond smelt, PW = pygmy whitefish, ISO = isopods.

[b] Calculated by: = {(R+1)/(M+1)}*100 where: R = number of marked fish recaptured, and M = number of marked fish (Carlson et al. 1998).

[c] Actual smolt do not reflect estimated emigration prior to trap installation

APPENDIX C. SMOLT CATCHES BY TRAP

Appendix C1.–Number of sockeye salmon smolt caught by trap, by day, from the Chignik River, May 6 through July 7, 2009.

	Small Trap		Large Trap		Combined		Daily Proportion	
Date	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Small	Large
5/6	235	235	1,731	1,731	1966	1,966	12.0%	88.0%
5/7	242	477	1,435	3,166	1677	3,643	14.4%	85.6%
5/8	311	788	3,147	6,313	3458	7,101	9.0%	91.0%
5/9	662	1,450	3,670	9,983	4332	11,433	15.3%	84.7%
5/10	311	1,761	1,909	11,892	2220	13,653	14.0%	86.0%
5/11	201	1,962	1,391	13,283	1592	15,245	12.6%	87.4%
5/12	461	2,423	1,623	14,906	2084	17,329	22.1%	77.9%
5/13	442	2,865	1,944	16,850	2386	19,715	18.5%	81.5%
5/14	607	3,472	1,829	18,679	2436	22,151	24.9%	75.1%
5/15	220	3,692	3,128	21,807	3348	25,499	6.6%	93.4%
5/16	442	4,134	1,274	23,081	1716	27,215	25.8%	74.2%
5/17	128	4,262	574	23,655	702	27,917	18.2%	81.8%
5/18	82	4,344	1,219	24,874	1301	29,218	6.3%	93.7%
5/19	81	4,425	654	25,528	735	29,953	11.0%	89.0%
5/20	58	4,483	253	25,781	311	30,264	18.6%	81.4%
5/21	16	4,499	108	25,889	124	30,388	12.9%	87.1%
5/22	31	4,530	334	26,223	365	30,753	8.5%	91.5%
5/23	26	4,556	78	26,301	104	30,857	25.0%	75.0%
5/24	23	4,579	303	26,604	326	31,183	7.1%	92.9%
5/25	42	4,621	1,058	27,662	1100	32,283	3.8%	96.2%
5/26	19	4,640	522	28,184	541	32,824	3.5%	96.5%
5/27	9	4,649	79	28,263	88	32,912	10.2%	89.8%
5/28	11	4,660	70	28,333	81	32,993	13.6%	86.4%
5/29	8	4,668	44	28,377	52	33,045	15.4%	84.6%
5/30	2	4,670	9	28,386	11	33,056	18.2%	81.8%
5/31	4	4,674	13	28,399	17	33,073	23.5%	76.5%
6/1	6	4,680	103	28,502	109	33,182	5.5%	94.5%
6/2	17	4,697	119	28,621	136	33,318	12.5%	87.5%
6/3	6	4,703	13	28,634	19	33,337	31.6%	68.4%
6/4	7	4,710	14	28,648	21	33,358	33.3%	66.7%
6/5	2	4,712	19	28,667	21	33,379	9.5%	90.5%
6/6	1	4,713	4	28,671	5	33,384	20.0%	80.0%
6/7	3	4,716	22	28,693	25	33,409	12.0%	88.0%
6/8	4	4,720	23	28,716	27	33,436	14.8%	85.2%
6/9	2	4,722	12	28,728	14	33,450	14.3%	85.7%
6/10	7	4,729	15	28,743	22	33,472	31.8%	68.2%
6/11	3	4,732	3	28,746	6	33,478	50.0%	50.0%
6/12	2	4,734	10	28,756	12	33,490	16.7%	83.3%
6/13	2	4,736	14	28,770	16	33,506	12.5%	87.5%
6/14	9	4,745	29	28,799	38	33,544	23.7%	76.3%
6/15	7	4,752	20	28,819	27	33,571	25.9%	74.1%

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	Small Trap		Large Trap		Combined		Daily Proportion	
Date	Daily	Cumulative	Daily	Cumulative	Daily	Cumulative	Small	Large
6/16	4	4,756	33	28,852	37	33,608	10.8%	89.2%
6/17	2	4,758	7	28,859	9	33,617	22.2%	77.8%
6/18	0	4,758	8	28,867	8	33,625	0.0%	100.0%
6/19	7	4,765	8	28,875	15	33,640	46.7%	53.3%
6/20	3	4,768	4	28,879	7	33,647	42.9%	57.1%
6/21	2	4,770	5	28,884	7	33,654	28.6%	71.4%
6/22	0	4,770	9	28,893	9	33,663	0.0%	100.0%
6/23	2	4,772	4	28,897	6	33,669	33.3%	66.7%
6/24	2	4,774	2	28,899	4	33,673	50.0%	50.0%
6/25	2	4,776	2	28,901	4	33,677	50.0%	50.0%
6/26	1	4,777	5	28,906	6	33,683	16.7%	83.3%
6/27	1	4,778	5	28,911	6	33,689	16.7%	83.3%
6/28	2	4,780	2	28,913	4	33,693	50.0%	50.0%
6/29	0	4,780	8	28,921	8	33,701	0.0%	100.0%
6/30	4	4,784	11	28,932	15	33,716	26.7%	73.3%
7/1	5	4,789	19	28,951	24	33,740	20.8%	79.2%
7/2	2	4,791	10	28,961	12	33,752	16.7%	83.3%
7/3	7	4,798	17	28,978	24	33,776	29.2%	70.8%
7/4	62	4,860	24	29,002	86	33,862	72.1%	27.9%
7/5	3	4,863	9	29,011	12	33,874	25.0%	75.0%
7/6	2	4,865	13	29,024	15	33,889	13.3%	86.7%
Total		4,865		29,024		33,889	14.4%	85.6%

APPENDIX D. CLIMATOLOGICAL OBSERVATIONS

Appendix D1.–Daily climatological observations for the Chignik River sockeye salmon smolt project, 2009.

Date[a]	Time	Air (°C)	Water (°C)	Cloud[b] Cover %	Wind[b] Dir	Vel.[b] (mph)	Trap Revolutions (rpm) Small	Large	Stream Gauge (cm)	Comments
5/6	11:50	3.0	3.0	30%	SE	10-15	8.00	8.00	109	Traps in at 10:00 (smolt date 5/5)
5/7	11:48	3.0	3.0	0%	NW	0-5	8.00	6.00	109	
5/8	12:01	6.0	3.5	0%	NW	0-5	7.50	6.50	109	
5/9	12:02	3.5	3.5	20%	NW	10-15	7.00	6.50	109	Dye test release @ 2342
5/10	12:02	3.5	4.0	5%	NW	20-25	7.00	6.50	105	
5/11	11:58	3.5	4.0	20%	NW	10-15	6.75	6.00	100	
5/12	12:00	8.5	5.0	0%	NW	10-15	7.50	6.25	100	
5/13	11:59	8.0	5.0	0%	SE	0-5	6.25	6.00	100	
5/14	12:02	9.0	5.0	5%	NW	5-10	6.75	6.00	100	
5/15	12:00	11.5	5.5	30%	NW	0-5	6.50	6.00	100	
5/16	12:06	7.0	5.0	10%	NW	5-10	6.75	6.25	100	Dye test release @ 2302
5/17	11:52	10.0	5.0	100%	SE	0-5	6.75	6.25	96	
5/18	11:58	7.5	5.0	100%	NW	5-10	6.75	6.25	96	
5/19	12:07	5.5	5.0	95%		0	6.75	6.25	98	
5/20	12:08	5.0	5.0	95%	NW	5-10	6.75	6.25	98	
5/21	12:03	5.0	5.0	70%	SE	5-10	6.25	5.75	94	Dye test release @ 2316
5/22	12:04	8.5	5.5	40%	NW	5-10	6.25	6.00	94	
5/23	11:57	7.0	5.5	100%	NW	5-10	6.00	5.75	94	
5/24	11:57	10.5	6.0	40%	NW	5-10	6.00	5.75	94	
5/25	11:58	6.5	5.5	100%	NW	10-15	6.00	5.75	93	
5/26	12:01	6.0	6.5	20%	NW	35-40	6.25	6.00	97	Dye test release @ 2315
5/27	12:04	11.0	6.5	20%	NW	15-20	6.25	5.75	99	
5/28	11:53	7.0	6.5	100%	NW	0-5	6.25	6.00	101	Drizzle
5/29	11:52	9.5	7.0	10%		0	6.25	6.00	101	
5/30	12:00	7.0	6.5	100%	SE	0-5	6.00	5.75	100	Rain
5/31	12:00	6.0	6.5	100%	SE	0-5	6.00	6.00	97	Adjusted traps, moved farther from shore
6/1	11:52	7.5	6.5	100%	SE	0-5	7.25	6.75	115	Gauge height taken at new site
6/2	17:32	7.0	6.5	100%	SE	0-5	8.50	7.50	127	Sampling Bear Lake at noon check
6/3	12:06	7.5	6.5	100%	SE	0-5	8.50	7.50	130	

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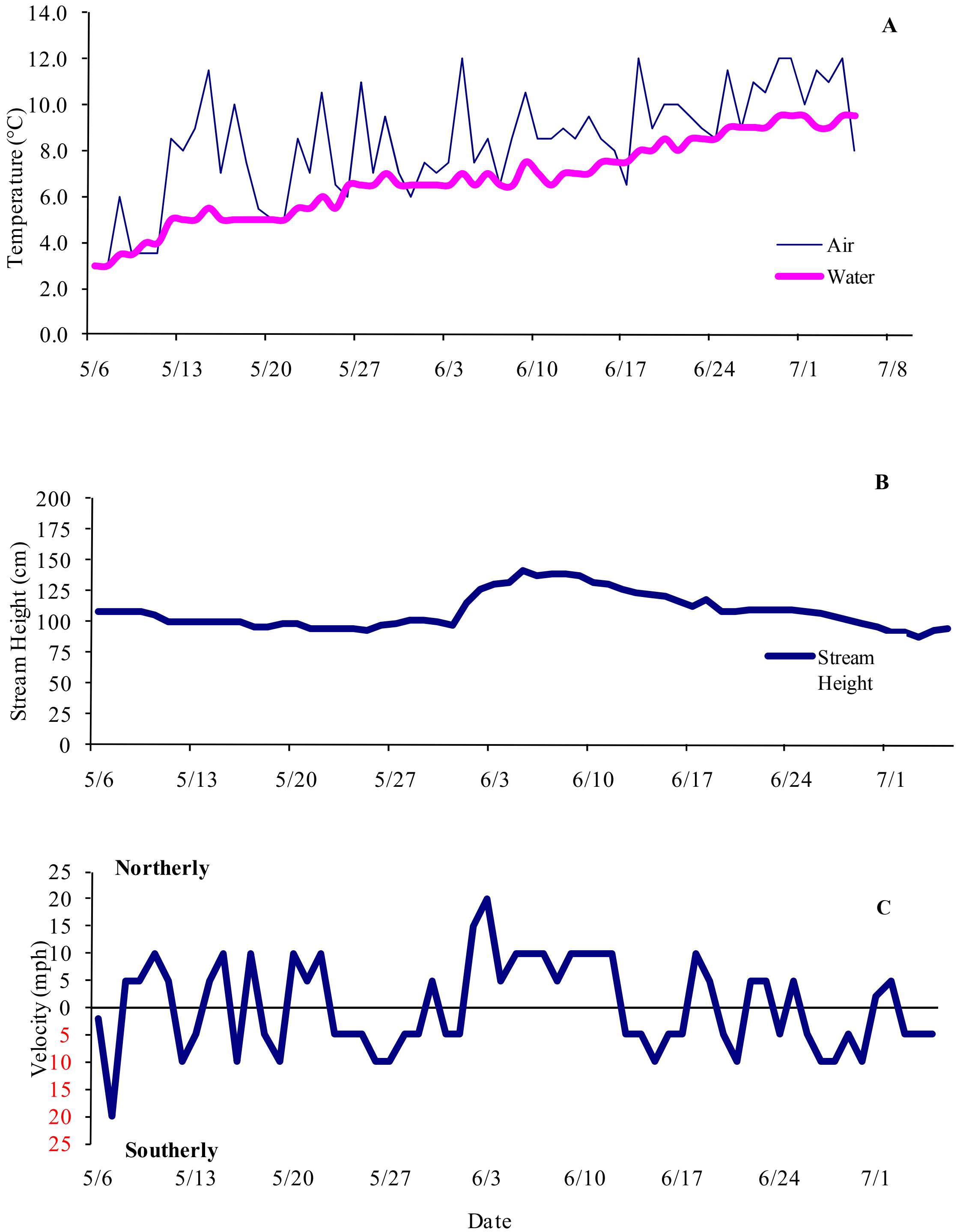
Date[a]	Time	Air (°C)	Water (°C)	Cloud[b] Cover (%)	Wind[b] Dir	Vel.[b] (mph)	Trap Revolutions (rpm) Small	Large	Stream Gauge (cm)	Comments
6/4	12:01	12.0	7.0	95%	SE	0-5	8.75	7.75	132	
6/5	11:57	7.5	6.5	100%	NW	10-15	9.25	8.00	141	Adjusted traps, moved closer to shore
6/6	11:52	8.5	7.0	5%	SE	0-5	8.50	7.75	138	Gauge height taken at new site
6/7	11:58	6.5	6.5	100%	SE	0-5	8.75	7.75	139	
6/8	12:08	8.5	6.5	100%	SE	0-5	8.50	7.75	139	
6/9	11:57	10.5	7.5	30%	SE	5-10	8.25	7.75	138	
6/10	12:03	8.5	7.0	40%	SE	5-10	7.50	7.25	132	
6/11	11:45	8.5	6.5	100%	SE	5-10	8.00	7.00	131	
6/12	12:00	9.0	7.0	100%	NW	5-10	7.25	6.75	127	
6/13	12:02	8.5	7.0	100%	NW	5-10	7.00	6.75	124	
6/14	11:58	9.5	7.0	30%	NW	5-10	6.75	6.5	122	
6/15	11:59	8.5	7.5	30%	SE	0-5	7.25	6.75	121	
6/16	12:06	8.0	7.5	100%	SE	10-15	6.00	5.75	117	
6/17	11:57	6.5	7.5	100%	SE	5-10	6.00	6.00	113	
6/18	12:03	12.0	8.0	90%	SE	0-5	6.25	6.00	118	Adjusted traps, moved farther from shore
6/19	12:05	9.0	8.0	100%	NW	5-10	6.00	6.00	108	Gauge height taken at new site
6/20	12:00	10.0	8.5	50%	NW	0-5	6.00	6.00	108	
6/21	11:55	10.0	8.0	95%	NW	0-5	6.00	5.50	110	
6/22	11:57	9.5	8.5	95%	SE	0-5	6.00	6.00	110	
6/23	12:03	9.0	8.5	90%	SE	0-5	6.00	5.50	110	
6/24	11:58	8.5	8.5	100%	SE	0-5	6.00	6.00	110	Adjusted traps to capacity, farther from shore
6/25	12:00	11.5	9.0	35%	NW	10-15	6.25	6.00	108	Gauge height taken at new site
6/26	12:05	9.0	9.0	40%	NW	15-20	6.00	6.00	107	
6/27	11:56	11.0	9.0	20%	NW	10-15	5.75	5.50	104	
6/28	12:00	10.5	9.0	90%	NW	5-10	5.75	5.25	102	
6/29	12:10	12.0	9.5	10%	NW	5-10	5.25	5.25	99	
6/30	12:11	12.0	9.5	100%	NW	0-5	4.75	5.00	96	
7/1	12:04	10.0	9.5	100%	SE	5-10	4.75	4.50	92	
7/2	12:04	11.5	9.0	100%	SE	5-10	4.50	4.50	92	
7/3	12:11	11.0	9.0	100%	SE	0-5	4.00	4.25	88	
7/4	12:03	12.0	9.5	100%	SE	0-5	4.50	4.25	93	
7/5	12:00	8.0	9.5	100%	SE	0-5	4.75	4.75	95	
7/6	12:07	18.0	10.5	90%	SE	0-5	4.50	4.75	95	

[a] Actual calendar dates.

[b] Based on observer estimates.

Appendix D2.–Air and water temperature (A), stream gauge height (B), and wind velocity and direction data (°C) gathered at the Chignik River smolt traps, 2009.



APPENDIX E. HISTORICAL AGE COMPOSITION DATA

Appendix E1.–Estimated age composition of Chignik River sockeye salmon smolt samples, 1994–2009.

		Sample		Number of Smolt				
Year	Dates	Size		Age-0.	Age-1.	Age-2.	Age-3.	Age-4.
1994	5/6-6/30	2,806	Percent	0.0	61.1	38.9	0.0	0.0
			Numbers	0	1,715	1,091	0	0
1995	5/6-6/29	2,557	Percent	10.7	49.8	39.5	0.0	0.0
			Numbers	273	1,274	1,010	0	0
1996	5/6-7/28	2,099	Percent	6.0	67.8	26.1	0.1	0.0
			Numbers	125	1,423	548	3	0
1997	5/4-7/22	2,657	Percent	7.3	63.1	29.1	0.5	0.0
			Numbers	195	1,676	774	12	0
1998	5/2-7/30	2,745	Percent	0.5	28.6	70.1	0.7	0.0
			Numbers	15	785	1,925	20	0
1999	5/10-7/3	2,180	Percent	1.8	61.7	36.1	0.3	0.0
			Numbers	40	1,345	788	7	0
2000	4/22-7/20	1,915	Percent	11.6	61.4	26.3	0.7	0.0
			Numbers	223	1,175	503	14	0
2001	4/29-7/12	2,195	Percent	4.4	75.0	17.7	2.8	0.0
			Numbers	96	1,647	389	62	1
2002	5/01-7/8	2,038	Percent	10.6	77.9	11.1	0.3	0.0
			Numbers	217	1,588	227	6	0
2003	4/25-7/8	2,098	Percent	7.1	79.6	13.3	0.0	0.0
			Numbers	149	1,670	279	0	0
2004	5/6-7/1	1,651	Percent	21.0	62.4	16.6	0.0	0.0
			Numbers	347	1,030	274	0	0
2005	4/26-7/8	1,950	Percent	33.5	45.7	20.4	0.4	0.0
			Numbers	654	892	397	7	0
2006	4/27-7/9	1,644	Percent	26.2	40.3	31.6	1.9	0.0
			Numbers	430	663	519	32	0.0
2007	5/9-7/8	1,087	Percent	0.6	74.4	25.0	0.0	0.0
			Numbers	6	809	272	0	0
2008	5/9-7/9	1,717	Percent	33.1	49.2	16.8	1.0	0.0
			Numbers	568	844	288	17	0
2009	5/6-7/7	1,201	Percent	16.6	49.0	34.4	0.0	0.0
			Numbers	199	589	413	0	0

APPENDIX F. HISTORICAL LIMNOLOGY DATA

Appendix F1.–Seasonal averages of water quality parameters, nutrient concentrations, and photosynthetic pigments by year for Black Lake, 2000–2009.

	2000	2001	2002	2003	2004	2005	2006[b]	2007[b]	2008[b]	2009
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
pH	7.43	7.53	7.45	7.46	7.81	7.62	8.01	7.64	7.64	7.7
Alkalinity (mg/L)	13.0	32.5	32.3	32.3	30.2	25.00	20.5	19.7	19.0	23.5
Total P (mg/L P)	57.0	35.0	22.0	41.7	22.2	27.93	20.4	24.43	22.23	41.1
TFP (mg/L P)	11.0	10.0	10.0	9.8	5.1	8.58	ND	ND	ND	ND
FRP (μg/L P)	4.0	7.0	5.0	5.8	2.6	7.20	9.1	ND	ND	ND
TKN (μg/L N)	ND	ND	323.5	256.8	188.8	324.5	216.0	124.3	263.7	233.5
Ammonia (μg/L N)	37.0	3.3	4.4	3.7	9.7	3.9	11.0	130.1	3.7	2.6
Nitrate + Nitrite (μg/L N)	64.0	4.5	8.3	25.2	3.7	1.93	0.9	1.57	0.6	1.3
Chlorophyll *a* (μg/L)	18.06	4.26	2.64	5.12	3.60	4.97	4.44	3.28	6.56	3
Phaeophytin *a* (μg/L)	9.98	11.94	1.44	1.78	0.15	0.98	0.76	0.93	1.42	1.4

[b] No limnological sampling occurred in August

Appendix F2.–Seasonal averages of water quality parameters, nutrient concentrations, and photosynthetic pigments by year for Chignik Lake, 2000–2009.

	2000	2001	2002	2003	2004	2005	2006[b]	2007[b]	2008[b]	2009
	Average	Average	Average	Average	Average	Average	Average	Average	Average	Average
pH	7.8	7.5	7.5	7.4	7.6	7.6	7.7	7.5	7.5	7.5
Alkalinity (mg/L)	15.1	24.8	24.6	23.6	22.4	23.8	24.8	18.2	21.0	22.9
Total P (mg/L P)	13.2	27.6	19.7	16.7	18.5	15.8	16.0	14.2	15.6	22.3
TFP (mg/L P)	5.3	12.2	8.5	7.5	6.5	6.6	ND	ND	ND	ND
FRP (mg/L P)	4.8	8.4	4.6	5.8	4.1	6.0	8.90	ND	ND	ND
TKN (mg/L N)[b]	230.0	99.5	119.7	99.0	146.5	199.5	86.0	148.3	96.3	79.8
Ammonia (mg/L N)	29.8	10.3	10.5	10.1	9.1	6.2	14.1	7.9	4.7	5.8
Nitrate + Nitrite (mg/L N)	102.6	132.9	117.4	166.6	128.0	110.9	129.9	194.0	192.5	151.8
Chlorophyll *a* (mg/L)	9.47	4.69	2.34	2.30	4.02	3.27	6.60	2.19	2.15	2.3
Phaeophytin *a* (mg/L)	1.69	1.31	1.34	0.51	0.32	0.65	0.90	0.37	0.56	0.6

[b] No limnological sampling occurred in August

Appendix F3.–Seasonal average number of zooplankton per m^2 from Black Lake, by year, 2005–2009.

Taxon	2005	2006[a]	2007[a]	2008[a]	2009
Copepods					
Epischura	18,113	-	5,750	-	3,729
Ovig. *Epischura*	-	-	-	-	-
Diaptomus	3,716	796	3,185	-	2,490
Ovig. *Diaptomus*	266	-	-	-	-
Cyclops	46,842	31,582	5,662	13,093	24,031
Ovig. *Cyclops*	-	-	-	-	-
Harpaticus	-	266	-	-	-
Napulii	38,150	7,564	9,996	16,189	28,938
Total copepods	107,086	40,207	24,593	29,282	59,188
Cladocerans					
Bosmina	203,755	2,323	1,858	1,681	49,209
Ovig. *Bosmina*	29,990	796	-	1,681	12,142
Daphnia l.	-	-	-	-	66
Ovig. *Daphnia l.*	-	-	-	-	-
Chydorinae	12,407	3,052	2,919	-	-
Total cladocerans	246,152	6,171	4,777	3,362	61,417
Total copepods + cladocerans	353,238	46,378	29,370	32,643	120,605

[a] No limnological sampling occurred in August

Appendix F4.–Average weighted biomass estimates (mg dry weight/m^2) of the major Black Lake zooplankton taxa by year, 2005–2009.

Taxon	2005	2006[a]	2007[a]	2008[a]	2009
Copepods:					
Epischura	14.3	-	28.3	-	3.3
Diaptomus	8.3	1.1	8.7	-	5.7
Cyclops	44.3	22.1	10.4	13.8	24.2
Harpaticus	-	0.2	-	-	-
Total copepods	66.8	23.4	47.4	13.8	33.1
Cladocerans:					
Bosmina	180.7	2.1	1.0	1.5	49.6
Ovigerous *Bosmina*	43.0	0.8	-	2.6	19.9
Daphnia longiremis	-	-	-	-	-
Chydorinae	8.7	1.8	6.2	-	-
Total cladocerans	232.4	4.8	7.2	4.0	69.4
Total Biomass	299.2	28.2	54.6	17.8	102.6

[a] No limnological sampling occurred in August

Appendix F5.–Seasonal average number of zooplankton per m^2 from Chignik Lake, by year, 2005–2009.

Taxon	2005	2006[a]	2007[a]	2008[a]	2009
Copepods:					
Epischura	14.3	-	28.3	-	3.3
Diaptomus	8.3	1.1	8.7	-	5.7
Cyclops	44.3	22.1	10.4	13.8	24.2
Harpaticus	-	0.2	-	-	-
Total copepods	66.8	23.4	47.4	13.8	33.1
Cladocerans:					
Bosmina	180.7	2.1	1.0	1.5	49.6
Ovigerous *Bosmina*	43.0	0.8	-	2.6	19.9
Daphnia longiremis	-	-	-	-	-
Chydorinae	8.7	1.8	6.2	-	-
Total cladocerans	232.4	4.8	7.2	4.0	69.4
Total Biomass	299.2	28.2	54.6	17.8	102.6

[a] No limnological sampling occurred in August

Appendix F6.–Average weighted biomass estimates (mg dry weight/m^2) of the major Chignik Lake zooplankton taxa by year, 2005–2009.

Taxon	2005	2006[a]	2007[a]	2008[a]	2009
Copepods					
Epischura		43.4	5.5	8.1	11.3
Ovig. *Epischura*		-	-	-	-
Diaptomus		121.3	37.7	53.2	109.6
Ovig. *Diaptomus*		23.1	28.4	89.0	-
Cyclops		153.9	300.7	557.8	147.2
Ovig. *Cyclops*		49.3	138.7	69.0	10.1
Harpaticus		0.2	1.0	4.3	0.1
Total Copepods:		391.2	463.1	781.5	278.3
Cladocerans					
Bosmina		79.4	36.8	11.2	18.9
Ovig. *Bosmina*		31.0	12.2	12.0	12.0
Daphnia longiremis		19.2	10.2	31.0	6.9
Ovig. *Daphnia longi*		19.2	2.8	32.5	6.4
Chydorinae		4.0	6.6	4.6	0.3
Total Cladocerans:		152.8	68.6	91.3	44.6
Total Biomass		544.0	586.1	872.8	322.8

[a] No limnological sampling occurred in August

APPENDIX G. DISTRIBUTION LIST

Appendix G1.–Distribution List

Individual	Organization	Address	# of copies
Chuck McCallum	Chignik Regional Aquaculture Assn.	2731 Meridian #B Bellingham WA 98225	10
Chuck McCallum	Lake and Peninsula Borough	1577 C St. Suite 330 Anchorage AK 99501	1
Bruce Barrett	Chignik Regional Aquaculture Assn.	P.O. Box 322 Lakeside MT 59922	1
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